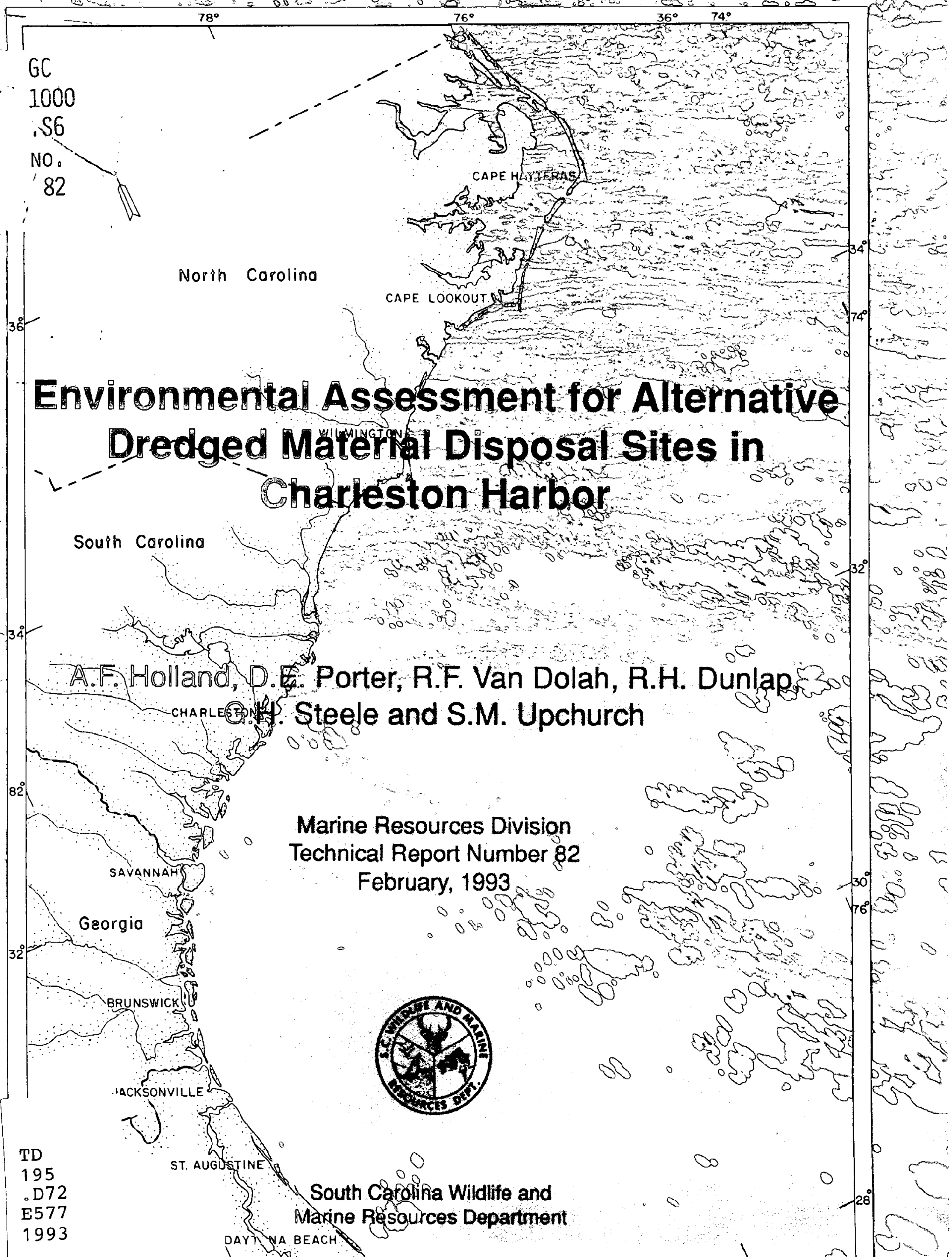

Environmental Assessment for Alternative Dredged Material Disposal Sites in Charleston Harbor

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Marine Resources Department

Environmental Assessment for

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by

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Executive Summary

Charleston Harbor is one of the most valuable economic resources in South Carolina and has a major role in national defense as a Navy home port. Large numbers of jobs and tax revenues result from the investments made in port facilities. The Harbor is also a valuable environmental resource providing spawning and nursery habitat for recreationally and commercially important fish and shellfish. The Harbor is used extensively for recreational fishing, shrimping, and boating.

The maintenance and development of navigational channels in Charleston Harbor is critical to the regional economy and national security. Annually, more than five million cubic yards of material must be removed from channels to maintain water depths required by shipping traffic. Construction of planned new port facilities and deepening of the Harbor to support a broader range of vessels will require more than twelve million cubic yards of additional dredged material disposal capacity. Activities associated with dredging, particularly the disposal of dredged material, may have substantial adverse impacts upon environmental resources.

Currently, the majority of material dredged from Charleston Harbor is deposited at a site located on the southern portion of Daniel Island which has large capacity, low environmental impact, and is economical to use. Unfortunately, the lease agreement for the use of Daniel Island expired in 1992, and the owner plans to develop the site into a community including residential housing, light industry, a shipping terminal, recreational space, and associated support services (e.g., schools).

Due to the impending loss of Daniel Island as a dredged material disposal site, the U.S. Army Corps of Engineers (USACOE) working with the South Carolina Coastal Council, the State Ports Authority (SPA), the U.S. Navy, and the City of Charleston initiated a study to identify alternatives to Daniel Island that have acceptable economic costs and environmental impacts. The USACOE was lead agency for conduct of the study and was responsible for the conduct of economic and engineering studies. The S.C. Wildlife and Marine Resources Department, Marine Resources Division (MRD), was contracted to conduct analyses to identify alternatives to Daniel Island that could sustain acceptable levels of environmental impacts. The alternative of not dredging the Harbor was not considered because the resultant economic and national security impacts were considered unacceptable.

MRD worked with the USACOE, other state and federal agencies, and the public, to identify alternative dredged material disposal sites that could be used *in lieu* of Daniel Island. Twenty prospective sites that had disposal capacities ranging from about one million cubic yards to 120 million cubic yards were identified. The areal extent of these sites ranged from 49 acres to over 9,800 acres. Sixteen were diked upland sites, two were diked estuarine sites, and two were uncontained ocean disposal sites. Six of the sites were existing dredged material disposal areas. The complete range of environmental conditions that exists in Charleston Harbor was represented by the alternative sites included in the evaluation. Multiple engineering configurations were evaluated for several sites.

MRD convened a workshop to define environmental concerns associated with construction and operations of dredged material disposal facilities in Charleston Harbor. Participants at the workshop included representatives of state and federal regulatory and resource management agencies, academic institutions, environmental advocacy groups, and cultural resource agencies. Environmental concerns associated with dredged material disposal facilities identified by participants at the workshop included:

- Impacts on existing environmental quality,
- Impacts on water quality,
- Critical habitat losses,
- Impacts on environments adjacent to candidate sites,
- Impacts on material cycles,
- Impacts on migration and movement patterns,
- Impacts on groundwater resources,
- Impacts on cultural resources,
- Impacts on human uses.

Projecting and contrasting the environmental consequences associated with siting of dredged material disposal facilities at the alternative sites required data collected in a standardized manner for all sites. MRD's review of the ecological literature for these sites found it to be fragmented, incomplete, and limited in spatial and temporal coverage. To overcome this problem, MRD developed a standardized data base of habitat types for the sites that provided data which could be used as a basis for projecting and evaluating environmental impacts for each of the environmental concerns identified. The habitat-cover data were developed using post-Hugo color infrared photography obtained by the National Aerial Photography Program (NAPP), existing nautical charts, and coastal bottom mapping data collected by the United States Environmental Protection Agency (EPA).

MRD developed quantitative measures (i.e., indicators) for projecting impacts associated with the environmental concerns identified at the workshop except impacts on groundwater and cultural resources. The South Carolina Water Resources Commission (WRC) was responsible for projecting impacts on groundwater resources, and Brockington and Associates, Inc., a Charleston based archaeological consulting firm, was responsible for projecting impacts on cultural resources. The indicators developed by MRD incorporated habitat-cover data and scientific knowledge about the sensitivity and vulnerability of habitats to estimate the relative magnitude of impacts associated with development of dredged material disposal facilities. The MRD analytical approach was also designed to allow the results obtained from WRC and Brockington and Associates, Inc. to be incorporated into the final assessment. Cumulative impacts were assessed by summing impacts across all environmental concerns. Environmental concerns were weighted equally for the cumulative impact assessment. Estimates of the degree of impact were adjusted for among-site differences in capacity to facilitate comparison of the alternatives. The final assessment we developed identified alternatives that had both small cumulative environmental impact and small environmental costs per cubic yard.

Major Conclusions were:

- None of the alternative sites were preferred habitat for threatened or endangered species or blocked migrational routes for recreationally and commercially important species.

- Existing diked dredged material disposal facilities at Yellow House Creek, Naval Weapons Station, Drum Island, and Clouter Creek were projected to represent the least threat to environmental resources and were the most acceptable alternatives to Daniel Island. These sites generally have large capacity and are located in regions of the Harbor where impacts on ecologically valuable resources are low. The smaller Ocean Dredged Material Disposal Site was also determined to be an acceptable alternative to Daniel Island for disposal of uncontaminated dredged material. The combined capacity of these existing disposal sites is about 240 million cubic yards. In combination, they provide most of the dredged material disposal capacity required for Charleston Harbor for the next 50 years.

- The most acceptable "new" site identified was Upper Thomas Island. Development of this site would provide about 25 million cubic yards of additional disposal capacity.

- Most of the sites do not warrant further evaluation as alternatives to Daniel Island because of the high environmental impact which would be associated with their development and use. Included in this group are the proposed Folly Beach Berm, modifications to the existing Morris Island disposal site, Patriots Point, Middle Shoal, Rodent Island alternatives, Lower Thomas Island, Fort Johnson, Cainhoy Road alternatives, Point Hope Island alternatives, and Parkers Island alternatives.

ACKNOWLEDGEMENTS

We wish to thank several people who assisted us on this study. Mr. Chris Brooks served as the contract officer for the South Carolina Coastal Council and expedited processing of the contract. He also provided technical input on the evaluation process. Mr. Mark Nelson served as the contract monitor for the U.S. Army Corps of Engineers, Charleston District, and served as a focal point for data transfers and technical reviews of findings. The cooperation and positive interactions that occurred between the South Carolina Marine Resources Division and the U.S. Army Corps of Engineers as part of this contract were largely a direct result of Mark's enthusiasm and dedication to making the project a success. Several other representatives from both state and federal agencies participated in a workshop that was instrumental in developing the criteria used in the evaluation of each site (see Table 3-2 for a listing of the participants). Rick DeVoe, Dana Beach, David Cupka, Elizabeth Wenner and Heyward Robinson reviewed earlier drafts of this report, and Margaret Lentz assisted in its typing and preparation.

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Chapter 1

Introduction

A. Project Overview and Goals

This report presents the findings of a study to identify dredged material disposal sites for Charleston Harbor that represent the least risk to environmental resources and have adequate capacity to meet the short- and long-term disposal requirements for port facilities. The general approach used was to identify as many alternative sites as possible and then use available information to evaluate and select among them based on the degree of relative environmental impact. The alternative of not dredging Charleston Harbor was not evaluated because the economic and national security consequences were considered unacceptable.

The results of this environmental evaluation will be integrated with the findings of an economic and engineering assessment conducted by U.S. Army Corps of Engineers (USACOE). The integrated assessment will define disposal sites that are projected to represent the least risk to environmental resources, have adequate capacity to meet short- and long-term disposal capacity for Charleston Harbor, and have acceptable economic cost. In development of the integrated assessment, results of the environmental evaluation will be weighted equally with the findings of the engineering/economic assessment. Results of the environmental and engineering/economic evaluations are scheduled for completion by February 1993. The integrated assessment is scheduled for completion in Spring 1993. Detailed environmental, economic, and engineering studies will then be conducted to better define the problems and issues associated with the preferred alternative(s).

The South Carolina Marine Resources Division (MRD) was the lead agency for the evaluation of impacts on environmental resources. MRD was assisted in this evaluation by the U.S. Fish and Wildlife Service (USFWS) Enhancement Field Office. The evaluation conducted by MRD and USFWS did not address impacts on groundwater or cultural resources. MRD and USFWS also did not evaluate impacts on human uses other than those associated with fishing, hunting, boating, and aesthetic pleasures, such as bird-watching. Impacts on groundwater resources were evaluated by the South Carolina Water Resources Commission (WRC) at the request of the USACOE. As the state agency responsible for management and protection of groundwater resources, WRC had the expertise and information required to conduct this assessment. The evaluation of impacts on cultural resources was conducted by Brockington and Associates, Inc., an archaeological consulting firm located in Charleston, South Carolina. This firm has conducted many previous archaeological assessments in the Charleston region and is familiar with the findings of previous archaeological surveys for Charleston Harbor. Brockington and Associates, Inc. was contracted by the South Carolina Coastal Council to conduct the required assessment on cultural resources for the USACOE. The archaeological assessment conducted by Brockington and Associates, Inc., included an evaluation of the visual effects of candidate sites on cultural resources. The analytical approach developed by MRD for assessing environmental impacts was designed to allow the results of evaluations conducted by WRC for groundwater resources and Brockington and Associates, Inc. for cultural resources to be incorporated into an overall assessment of cumulative environmental impacts.

B. Background Information

The port of Charleston is composed of an extensive network of commercial, state, and federal facilities. It includes the Charleston Naval Base and commercial port facilities which represent the largest containerized cargo shipping and receiving facilities in the southeast (SPA 1989). Significant investments have been made to develop these facilities and their value to the regional economy is well established (SPA 1992). For example, 1,400 commercial vessels with a combined cargo of over seven million tons passed through the Port of Charleston during 1989. Port activities support approximately 60,000 jobs, $6.2 billion in sales, $1.5 billion in personal income, and $240 million in tax revenues annually (SPA 1992). Additionally, the third largest home port for the U.S. Navy is located in Charleston Harbor, supporting more than 70 surface vessels and submarines as well as a shipyard and Naval Weapons Station. In 1985, over 59,500 military and civilian personnel with a total payroll and local purchases of over $1.5 billion resulted from the naval base and related Department of Defense facilities (Campbell 1988).

Charleston Harbor also includes extensive wetland and estuarine habitats that provide spawning and nursery areas for many species of fish, shellfish, birds, and other wildlife (Shealy et al. 1974; Sandifer et al. 1980; Van Dolah et al. 1990; Chamberlain 1991). The Harbor's fishery resources are extensively used by recreational fishermen (Campbell 1988; Moore and Chamberlain 1991). Several historical tourist attractions, including Fort Sumter, Fort Moultrie, and the Patriots Point Maritime Museum, are located on the Harbor, and the scenic views that exist along the Harbor's shoreline are a valuable aesthetic resource. The protected waters of the Harbor are used for recreational boating with seven commercial marinas (approximately 1,200 slips) and 28 public boat landings occurring in the Harbor region (Davis and Van Dolah 1992).

The maintenance and development of navigational channels and turning basins in Charleston Harbor is critical to the regional economy and national security. Continual dredging activities are required to maintain channels and turning basins at desired water depths (Kjerfve 1976). About five million cubic yards of material are removed annually from the Harbor bottom since completion of the Santee River Rediversion Project (M. Nelson, USACOE, personal communication). In addition, the Charleston Harbor Deepening Project, scheduled for completion in the mid-1990's, will eventually remove more than twelve million cubic yards of material from the Harbor.

Dredging activities significantly impact environmental resources and other uses of the Harbor. Short-term impacts include increased turbidity and decreased abundance of bottom dwelling biota and fish (Windom 1976, Morton 1977, Allen and Hardy 1980). Marine turtles are also at risk of being entrained into some types of dredges (Ehrhart 1987, Butler et al. 1987, Dickerson et al. 1991, Van Dolah et al. 1992). The environmental impacts of greatest long-term concern to the public, however, are those associated with the consequences of dredged material disposal upon ecological, cultural, and aesthetic resources (Morton 1977). Of particular concern is the conversion of ecologically valuable wetland habitat into disposal areas.

Currently, a large portion of dredged material from Charleston Harbor is disposed of at a site located on the southern tip of Daniel Island, several disposal sites along the Cooper River, and an ocean disposal site south of the Charleston Harbor entrance channel. The Daniel Island disposal site has been important to the USACOE disposal strategy in Charleston Harbor for much of the past decade. Not only does this site have large capacity and relatively low ecological impact, but its central location makes it economical to use. Although the Daniel Island site has the disposal capacity that would allow its use for many more years, the lease agreement for Daniel Island between the USACOE and the Guggenheim Foundation expired in 1992 and may not be renewed. The Guggenheim Foundation plans to develop Daniel Island into a community that includes residential housing, light industry, a shipping terminal, recreational space, and associated support facilities (e.g., schools, churches). The plans to develop Daniel Island potentially adversely affect its future use as a disposal site for dredged material.

Due to the impending loss of Daniel Island as a dredged material disposal site, the USACOE initiated a study with the South Carolina Coastal Council, South Carolina State Ports Authority (SCSPA), the U.S. Navy, and the City of Charleston, to define an environmentally acceptable alternative(s) to the use of Daniel Island. The USACOE is responsible for conducting the study under an interagency agreement with the South Carolina Coastal Council. An Executive Steering Committee, composed of representatives of the five governmental agencies identified above, advises the USACOE on policy issues. A scientific advisory group, composed of representatives of state and federal regulatory and resource management agencies and concerned public interest groups, provides technical review of study plans and products.

C. Objectives

As noted above, the goal of this study was to identify dredged material disposal sites in Charleston Harbor which were projected to have adequate capacity to be an alternative to Daniel Island. Specific tasks required to accomplish this goal were to:

- Define the scope of MRD and USFWS technical support activities,
- Develop a list of alternative dredged material disposal sites including specification of site boundaries,
- Define environmental concerns associated with dredged material disposal operations in Charleston Harbor,
- Review and compile available environmental data for alternative disposal sites,
- Develop land-use/habitat-cover information for each site and use it as a basis for mapping site boundaries, development of engineering plans, and projection of environmental impacts,
- Develop an analytical approach for projecting impacts of construction and operations of possible dredged material disposal facilities on Charleston Harbor,
- Apply the analytical approach to identify environmentally acceptable alternatives to the use of Daniel Island, and
- Document results of the analysis in an environmental assessment report.

D. Report Organization

An Executive Summary has already been presented that provides a brief summary of the approach, findings, conclusions, and recommendations. The remainder of this report is organized in the following sections:

- Approach and Rationale (Chapter 2): This chapter defines the scope of the study and provides an overview of the approach used.

- Methods and Results (Chapter 3): This chapter provides a detailed description of the methods used for each task and presents detailed findings of the analyses, including results of sensitivity analyses.

- Conclusions and Recommendations (Chapter 4): This chapter integrates analytical results into conclusions and recommendations, including identification of environmentally acceptable alternatives to the use of the Daniel Island dredged material disposal site.

Chapter 2

Approach and Rationale

A. Introduction

An overview of the tasks that MRD conducted for this study as well as the relationship among them is shown in Figure 2-1. The sequence of tasks was designed to identify high priority environmental concerns early in the study and focus the evaluation on these high priority concerns. Sensitivity analyses were conducted to evaluate indicators used and assess the consequences of assumptions and subjective judgment on findings. The feedback loop in Figure 2-1 between tasks 3 (Review and Compile Available Data), 4 (Develop Analysis Methods), and 5 (Conduct Analysis), illustrate the iterative process used to refine analytical methods and results. Many different indicators of the degree and extent of environmental impacts were evaluated before an appropriate suite was selected. Task 6 provided the means for incorporating projected impacts on ground water and cultural resources developed by others into the assessment of cumulative environmental impact.

B. Coordination

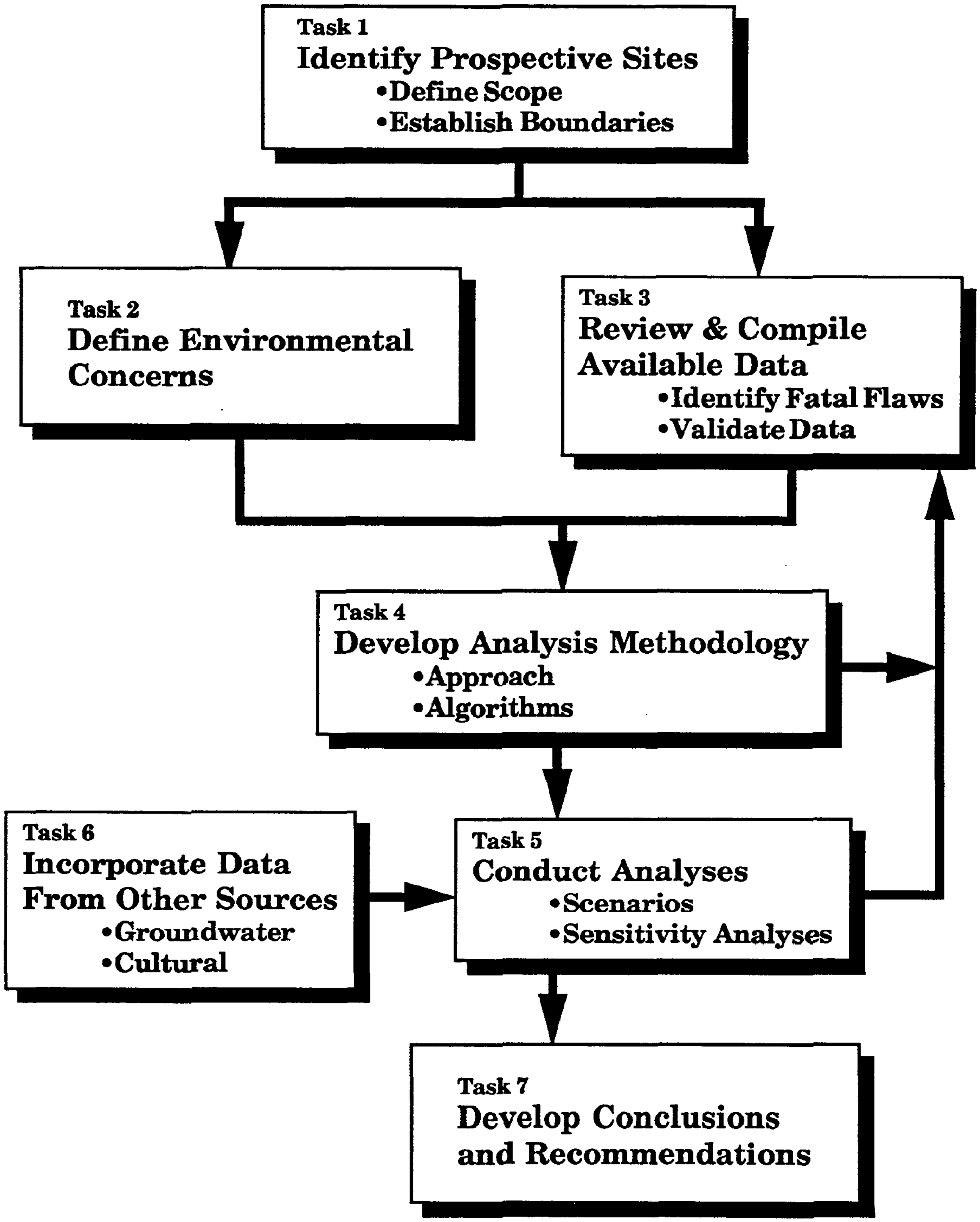
Regulatory and resource management agencies, technical experts, environmental groups, and the public were regularly informed of the progress and results of each task through briefings and workshops. This coordination improved the level of understanding of study methods and findings.

C. Study Scope

The list of sites included in the evaluation was developed jointly with the USACOE and other state, federal, and local resource management and regulatory agencies, academic scientists, technical experts, and the concerned public. The goal of this activity was to identify as many prospective sites and alternative engineering configurations that could be evaluated given the budget constraints of the project.

No major new data collection activities were conducted for this study. Field surveys were limited to site visits to verify existing information and refine site characterizations. The existing ecological condition (i.e., habitats and assemblages) for each site was developed by synthesizing and integrating existing ecological data into resource distribution maps that could be used to project the relative environmental consequences of construction and operation of dredged material disposal facilities.

Figure 2-1. Schematic showing study approach.



Assessment activities were focused on selected biota whose abundance, distribution, ecological role (e.g., food web linkage), or economic importance (e.g., recreationally harvested fish) are critical components of indigenous populations of fish, shellfish and other wildlife. These species were called Representative Important Biota (RIB) and were biota for which the most detailed and extensive ecological information was available. Scientific knowledge for RIB provided a basis for projecting impacts with a reasonable degree of confidence. Responses of RIB were assumed to be indicators of system wide responses. The RIB assessment approach has been extensively used for siting power plants and other types of industrial operations (Limberg et al. 1984).

RIB included biota that were sensitive to construction and operation of dredged material disposal sites as well as biota that have economic and ecological value. In addition, RIB selections included a range of trophic levels and other ecological classifications. Table 2-1 provides a list of selected RIB organized by ecological category. Appendix A provides a brief overview of the life history and ecology for each RIB.

In a similar manner, assessment activities were focused on a limited number of habitats whose abundance, distribution, and ecological value (e.g., nursery habitat for commercially and recreationally important species), or economic and ecological importance (e.g., live bottom reef habitat) were essential to the maintenance of indigenous populations of fish, shellfish, and other wildlife. These habitats were called Representative Important Habitats (RIHs). Scientific knowledge for RIHs provided the basis for projecting impacts associated with construction and operation of dredged material disposal facilities on RIHs. Responses of RIHs were considered to be indicators of system-wide responses. A list of the RIHs used for this study is provided in Table 2-2. This list includes habitats which are sensitive to construction and operation of dredged material disposal sites, as well as habitats of economic and ecological value. Appendix B provides a brief description of each RIH.

D. Identification of Fatal Flaws

This study was also designed to identify and eliminate alternative sites which had fatal flaws. Fatal flaws were defined as impacts which were projected to:

- Adversely impact an important habitat, particularly a refuge, for a threatened and/or endangered (T&E) species,

Table 2-1. List of Representative Important Biota.

Habitat Formers

- Reef sponges and soft corals
- Dune plants
- Saltwater marsh plants

Rare and Endangered Species

- Loggerhead turtle
- Red-cockaded woodpecker
- Canby's dropwort

Species sensitive to operation and construction of disposal sites

- Reef sponges and soft corals
- Oysters: Intertidal and subtidal
- Freshwater wetland plants

Commercially/Recreationally Important Species

- White shrimp
- Black sea bass
- Blue crab
- Red drum
- Eastern wild turkey

Aesthetically Important Species

- Great blue heron
- River otter
- American bottlenose dolphin

Table 2-2. List of Representative Important Habitats for which habitat-cover information was developed.

Existing Diked Disposal Areas

Upland Habitat

Freshwater Wetlands

Ponds, Borrow Pits, and Impoundments

Mixed Estuarine Marshes

High Elevation Marsh

Low Elevation Marsh

Tidal Sand and Mud Flats

Small Tidal Creeks

Large Tidal Creeks

Shallow (<2 m) Estuary

Deep (>2 m) Estuary

Coastal Dunes and Beaches

Shallow (<10 m) Coastal Water

Deep (>10 m) Coastal Water

Live-Bottom Habitat

Off-Shore Berm

- Adversely impact a cultural resource of national and/or regional significance, or

- Block migration and/or movement of recreationally and/or commercially important species.

Adverse impacts to T&E species were those projected to result in the permanent loss of a currently used habitat for T&E species which cannot be mitigated. Adverse impacts to cultural resources were actions projected to result in loss of or damage to resources of national or regional significance which cannot be mitigated by data collection and data recovery activities.

The USFWS Enhancement Field Office at Charleston provided MRD with species names and the approximate locations and known habitats of T&E species in the Charleston Harbor area. Based on this information and discussions with the non-game and endangered species staff of the South Carolina Wildlife and Marine Resources Department (SCWMRD), none of the candidate sites were determined to contain prime habitat for T&E species. T&E species, particularly plants, however, had the potential to occur at several of the sites. A detailed T&E evaluation will be required for these alternatives if they are selected for development into a dredged material disposal facility.

An evaluation of potential impacts on cultural resources was conducted by Brockington and Associates, Inc. (1992). Results of this evaluation were incorporated directly into analyses conducted for this report. None of the candidate sites were determined to have adverse impacts on cultural resources that could not be mitigated.

MRD determined that none of the proposed alternatives blocked an important migration route for recreationally and/or commercially important species (refer to discussion in Chapter 3, Section E.6).

E. <u>USFWS Responsibilities</u>

USFWS responsibilities included:

- Assisting with evaluations for T&E species,

- Participating in site visits,

- Providing support for development of habitat cover data,

- Planning and participating in technical workshops, and

- Conducting technical reviews.

F. MRD Responsibilities

MRD was responsible for completion of all tasks. In the next chapter, the specific methods used and findings for each task shown in Figure 2-1 are described.

Chapter 3

Methods and Results

A. Task 1: Identification of Alternative Sites and Establishment of Site Boundaries

The USACOE working with other federal [U.S. Environmental Protection Agency - Region IV (EPA-IV), U.S. Fish and Wildlife Service (USFWS), U.S. Navy, National Marine Fisheries Service (NMFS)], state [S.C. Department of Health and Environmental Control(DHEC), MRD, S.C. Sea Grant Consortium, S.C. Water Resources Commission (WRC), S.C. Land Resources Conservation Commission (SCLRCC)], and local (City of Charleston) agencies developed a preliminary list of seventeen alternative sites in September 1991. This list was presented to the public, environmental groups, and the scientific community at a series of meetings and workshops. As a result of these meetings, the list of candidate sites was expanded to the twenty listed in Table 3-1 and shown in Figure 3-1.

Sixteen of the alternative sites are diked upland disposal sites, two are diked estuarine disposal sites, and two are uncontained ocean disposal sites. Six sites are currently used for dredged material disposal. Four sites were historically used for dredged material disposal but are not currently active disposal sites. Multiple engineering configurations, representing a range of disposal capacities and potential impacts, were developed for many of the sites (Table 3-1). Several of the alternatives represent modifications to existing disposal sites (i.e., Morris Island and Yellow House Creek).

The disposal capacity of alternative sites range from slightly more than one million cubic yards for Patriots Point to about 120 million cubic yards for one of the Morris Island alternatives (Table 3-1). The long-term disposal needs of the USACOE (i.e., ≈240 million cubic yards for the next 50 years) will require use of multiple sites. Dredged material containing levels of contaminants that are toxic to biota cannot be placed at uncontained ocean disposal sites because these materials have a high risk of adversely impacting natural resources in ocean environments.

The USACOE was responsible for defining site boundaries. Preliminary boundaries for ocean disposal sites were provided to MRD as a series of geographic coordinates that defined the size and shape of ocean disposal areas. These boundaries were verified using latitudes and longitudes provided by EPA Region IV. Preliminary boundaries for the diked (i.e., non-ocean) disposal

Table 3-1. List of alternative sites including information on existing status and historical use, proposed disposal metho projected disposal capacity, and number of engineering configurations evaluated.

Site	Existing Site Status	Proposed Disposal Method	Projected Disposal Capacity (10^6cu yds)	Number of Configurations Evaluated
Yellow House Creek	Existing disposal site	D	91.6 52.2 & 39.4	3
Rodent Island	Undeveloped coastal island	D	28.6 & 35.6	2
TC Depot	Inactive disposal site	D	15.6	1
Naval Weapons Station	Existing disposal site	D	20.0	1
Upper Thomas Island	Partially developed coastal island	D	25.2	1
Clouter Creek	Existing disposal site	D	108.8	1
Lower Thomas Island	Partially developed coastal island	D	21.6	1
Old Landfill	Inactive disposal site	D	10.4	1
Drum Island	Existing disposal site	D	10.1	1
Patriots Point	Inactive disposal site	D	1.6	1
Middle Shoal	Natural estuarine shoal habitat	E	11.8	1
Fort Johnson	Inactive disposal site	D	25.4	1
Morris Island	Existing disposal site	D	39.0 76.4 & 119.0	3
Cainhoy Road	Undeveloped coastal island	D	67.0 & 74.0	2
Point Hope and Dutchman Islands	Undeveloped coastal islands	D	74.2 & 86.8	2
Parkers Island	Undeveloped coastal island	D	60.8 & 63.6	2
Town Creek	Natural tidal creek habitat	E	28.0	1
Daniel Island	Existing disposal site	D	55.2	1
Ocean Dredged Material Disposal Site (ODMDS)	Existing disposal site	O	51.0 & 51.0	2
Folly Beach Berm	Natural nearshore coastal habitat	O	5.0	1

D = diked upland disposal site
E = Contained estuarine disposal site
O = Uncontained ocean disposal site

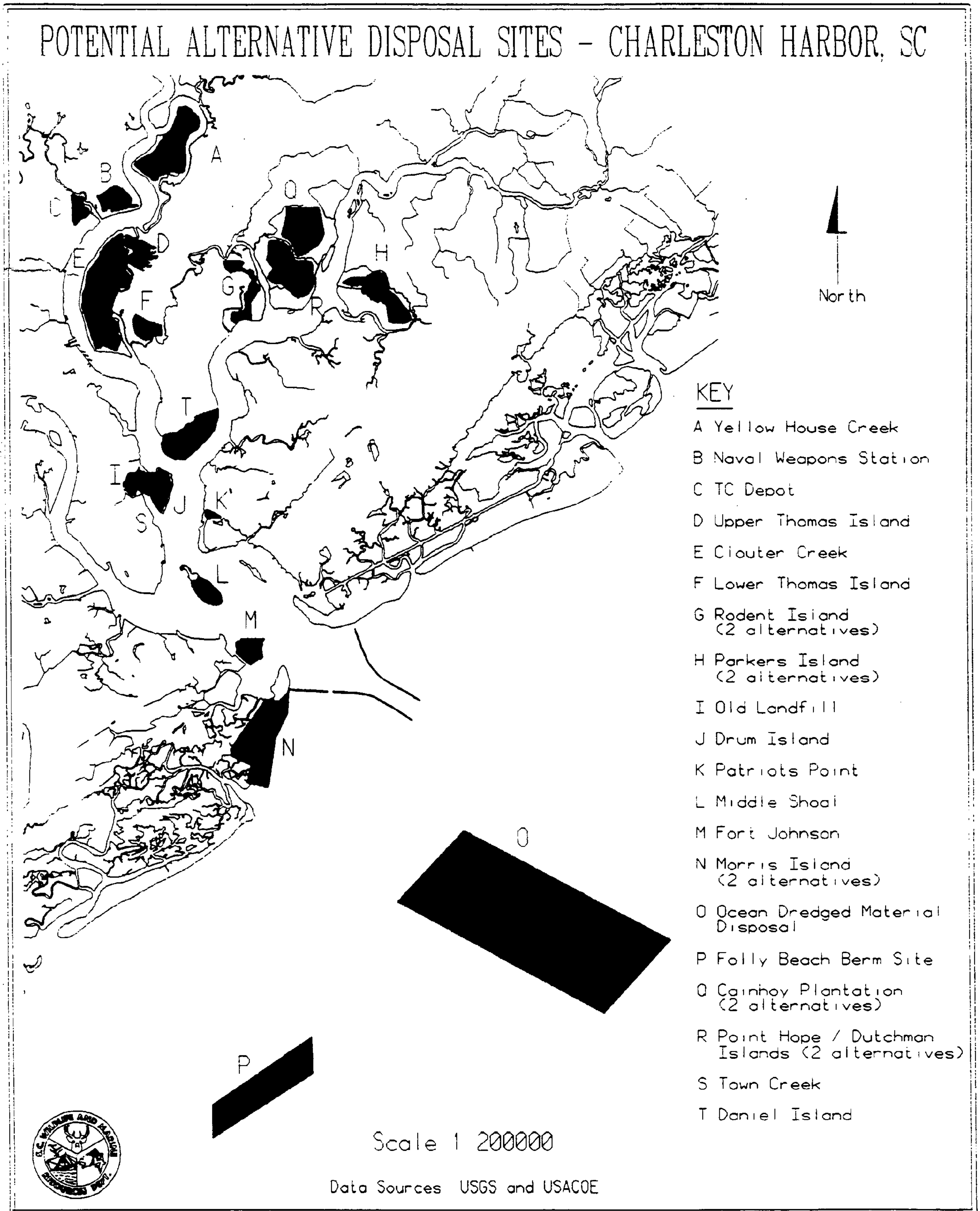


Figure 3-1. Potential alternative disposal sites for Charleston Harbor.

sites were provided as freehand drawings on photocopied 1:24000 United States Geological Survey (USGS) topographic maps. These preliminary boundaries were transferred to 1:24000 mylar USFWS National Wetland Inventory (NWI) maps that correspond to 1:24000 USGS topographical maps representing the Charleston Harbor area (i.e., James Island, Charleston, North Charleston, Cainhoy, and Fort Moultrie). The preliminary boundaries were manually digitized using vector-based GIS software. The southwest, northwest, northeast, and southeast corners of each map were used as registration points. Preliminary site boundaries were then transformed into Zone 17 of the Universal Transverse Mercator (UTM) projection system. Meters were used as the unit of measure. Using the information provided by MRD as well as through site visits, the USACOE refined the preliminary boundaries into the final engineering configurations.

Digital files of the preliminary site boundaries for non-ocean candidates were provided to the USACOE for review and approval. Ancillary information provided to assist the USACOE with the review included Post-Hugo National Aerial Photography Program (NAPP) 1:40000 color infrared photography (CIR) enlarged to a scale of 1:24000, NWI habitat-cover data, and data on primary and secondary roads.

B. Task 2: Identification of Environmental Concerns:

A workshop was convened by MRD on 24 March 1992 to define environmental concerns associated with construction and operations of dredged material disposal sites in Charleston Harbor. Workshop participants included representatives of state and federal regulatory and resource management agencies, academic institutions, environmental groups, and cultural resource agencies. A list of the agencies and participants attending the workshop is provided in Table 3-2.

Discussions at the workshop concluded that construction and operation of dredged material disposal sites in Charleston Harbor will adversely impact environmental resources in a broad variety of ways. Major environmental concerns that were identified included the following:

- Impacts on the existing environmental quality,
- Impacts on water quality,
- Critical habitat losses,
- Impacts on habitats adjacent to candidate sites,
- Impacts on material cycles,
- Impacts on migration and movement patterns,
- Impacts on groundwater resources,

Table 3-2. List of agencies and individuals that attended the workshop to define environmental concerns associated with construction and operation of dredged material disposal sites in Charleston Harbor.

Agency	Representatives
Federal Agencies	
U.S. Army Corps of Engineers (USACOE) Charleston District	Mr. M. Nelson
	Mr. J. Preacher
	Mr. J. Woody
	Mr. B. Kizer
U.S. Environmental Protection Agency (USEPA) Region IV	Ms. M. Farzaad
	Mr. G. Collins
United States Fish and Wildlife Service	Mr. E. Eudaly
National Marine Fisheries Service	Dr. G. Scott
	Mr. L. Hardy
Regional Organizations	
South Atlantic Fisheries Management Council	Mr. R. Pugliese
State Agencies	
S.C. Department of Health and Environmental Control	Ms. S. Nunnally
S.C. State Ports Authority	Mr. L. Setzler
S.C. Coastal Council	Mr. S. Snyder
	Mr. H. Robinson
S.C. Sea Grant Consortium	Mr. R. DeVoe
S.C. Land Resources Conservation Commission	Dr. R. Somers
S.C. Water Resources Commission	Mr. J. Havel
S.C. Wildlife and Marine Resources Department	Dr. R. Van Dolah
	Dr. F. Holland
	Dr. E. Wenner
	Ms. J. Settle
	Mr. R. Dunlap
	Mr. W. Anderson
	Ms. S. Upchurch
	Mr. G. Steele
	Mr. C. Moore
	Mr. D. Porter
	Mr. D. Whitaker
Academic Institutions	
The Citadel	Dr. R. Porcher
Environmental Groups	
S.C. Coastal Conservation League	Mr. D. Beach

- Impacts on cultural resources, and
- Impacts on human uses.

No justification was presented at the workshop which supported the position that any specific concern was more important than any other.

C. <u>Task 3: Review of Ecological Information and Development of a Habitat-Cover Data Base</u>

Projecting and contrasting the environmental impacts associated with the alternative disposal facilities required environmental data collected in a standardized way for all sites. A literature review, found the available data for prospective sites in Charleston Harbor to be fragmented, incomplete, and limited in spatial and temporal scope. Only one recent comprehensive study of aquatic ecological resources for Charleston Harbor was identified (Van Dolah et al. 1990, Davis and Van Dolah 1992). Recent comprehensive ecological information for ocean disposal sites was also limited to relatively few studies (e.g., Winn et al. 1989). Comprehensive ecological information characterizing terrestrial ecosystems for alternative disposal sites was not found.

Based on the literature review, it was determined that the only quantitative environmental information that was available or could be developed in a standardized manner for all sites was habitat-cover (i.e., land use/land cover) data. Several potential sources of habitat-cover information were identified (Lacy et al. 1991, USGS 1984). All were based on data collected prior to Hurricane Hugo (i.e., 21 September 1989) and were not representative of existing conditions.

Because the existing digital habitat-cover information was not representative of existing conditions, MRD developed "new" habitat-cover data for the Representative Important Habitats (RIHs) identified in Table 2-2. Habitat-cover data for non-ocean disposal sites was developed from Post-Hugo (1 February 1991) NAPP 1:40000 CIR photography obtained from the National Cartographic Information Center (NCIC). These data were selected because they:

- Were acquired during time periods when trees did not have leaves allowing a high degree of resolution among wetland classes, and
- Could be processed using standard photointerpretation methods.

The cost and time required to obtain and process habitat-cover data from satellite imagery was determined to be beyond the scope of this study. In addition, the degree of resolution for satellite imagery was determined to be inadequate to accomplish study goals.

The NAPP photography was photointerpretated using level III of the Florida Land Use, Cover, and Forms Classification System (FLUCCS) (Florida Department of Transportation 1985). FLUCCS was selected over the Anderson Classification System (Anderson et al. 1976) and the Cowardin Classification System (Cowardin et al. 1979) because it: (1) provided for both wetland and upland classifications, and (2) was specifically developed for Southeastern U.S. coastal applications. The Anderson System does not adequately classify coastal wetlands, and the Cowardin System does not adequately classify upland systems. Standard stereoscopic photointerpretation techniques were used.

Habitat-cover data were developed for each site and a 200-m wide buffer area adjacent to each site. Habitat cover in the buffer areas was obtained because it provided information to evaluate effects on adjacent environments. It also provided flexibility should it become necessary to modify site boundaries in the future. Photointerpretation was not accomplished for the entire Charleston Harbor region because the costs of acquiring these data exceeded the budget available to this project. In addition, these data were not required to accomplish study objectives.

MRD and USFWS conducted site visits to verify and correct the preliminary habitat-cover maps. The "groundtruthing" process consisted of verifying the extent, shape, and habitat type using available land marks and approximate distances. Positioning instrumentation (e.g., global positioning system, Loran) was not used. About 10% of the habitat-cover data was verified. All of the habitat-cover data for RIHs were, however, reviewed and qualitatively compared against information obtained during site visits and the CIR photography from which they were derived.

The verified photointerpreted data on habitat cover were transferred and registered to stable-based mylar USGS 1:24000 topographic maps and digitized. Registration of the habitat-cover data was consistent with the registration of site boundaries. The verified data were transformed into the UTM coordinate system, and a GIS data layer representing habitat cover for alternative non-ocean disposal sites produced.

Habitat-cover information for aquatic habitats was developed using information on water depth available from USGS and National Oceanic and Atmospheric Administration (NOAA) nautical charts, field experience of MRD staff, and site visits. These data were manually digitized and incorporated into the FLUCCS habitat-cover data base.

Reliable and documented data on habitat cover were available for only portions of alternative ocean disposal sites. Therefore, MRD developed habitat-cover information for the portions of candidate sites for which data were available, and used this information to infer habitat-cover condition for unsampled areas. The data used to produce maps of habitat cover for ocean disposal sites were collected by EPA during 1989 and consisted of a series of point observations taken along transects that indicated the presence or absence of specific habitats (i.e., sand bottom or live bottom habitat characterized by reef forming biota and/or structures). The area surveyed included the Ocean Disposal Material Disposal Site (ODMDS) as originally defined by the USACOE and a buffer area around the ODMDS extending several nautical miles to the south. The boundaries of the EPA study area as well as the locations of points characterized by live bottom habitat were digitized. Based on the distance between transect lines and the visual resolution of observational records along each transect, an area of 300 meters around data points identified as containing fauna characteristic of live bottom habitats was classified as live bottom habitat. The digitized data were transformed into the UTM coordinate system and stored.

Approximately fifteen percent of the ODMDS surveyed by EPA contained biota characteristic of live bottom habitat. The remainder was deep coastal sand bottom habitat. Analyses conducted for ODMDS alternative 1 used a value of fifteen percent live bottom cover and the maximum possible areal extent for the ODMDS site that has ever been approved by regulatory and resource management agencies. The fifteen percent estimate was considered to represent a "worst case" or maximum impact condition for ODMDS alternatives. The data on which this estimate is based were collected from locations within the ODMDS where live bottom habitat is particularly abundant. Substantially less than fifteen percent of the bottom of much of the ocean disposal area is actually live bottom habitat. Analyses for ODMDS alternative 2 used an estimate of five percent live bottom cover and a substantially reduced areal extent (i.e., 3,216 acres vs 9,843 acres). ODMDS alternative 2 was considered to represent the minimum impact condition for ODMDS alternatives.

No site specific data were available for estimating the amount of live bottom habitat present at the proposed site for the Folly Beach Berm. Based on the experience of MRD staff, we estimated that no more than one percent of this site would contain live bottom habitat. Recent surveys suggest that substantial amounts of live bottom habitat may occur in the vicinity of the proposed Folly Beach Berm suggesting this estimate may be conservative. A detailed survey of the proposed site of the Folly Beach Berm to define the extent of live bottom habitat actually occurring will be required before a berm could be constructed. Habitat-cover information for candidate sites is summarized in Table 3-3. Similar data for adjacent areas are presented in Table 3-4.

The RIHs defined for this study were a subset of the habitat classes defined by FLUCCS. Some FLUCCS categories were aggregated for analyses. For example, FLUCCS defines several categories of upland habitat (e.g., tree plantations, pine flatwoods, coastal scrub rangeland, open land, etc.). These categories were combined into a generic upland RIH class for this evaluation. In addition, several FLUCCS classes of freshwater wetlands were combined into one RIH freshwater wetland category. Table 3-5 lists the FLUCCS habitat classes that were combined to produce the data provided in Tables 3-3 and 3-4.

D. Task 4: Development of Assessment Methods

An overview of the analysis scheme developed for conducting assessments is shown in Table 3-6. The columns in the matrix represent the alternative engineering configurations for prospective sites. Rows 2-10 represent the environmental concerns identified at the workshop as contributing to cumulative environmental impacts. The cells in the matrix contain the scores calculated for each environmental concern at each site using algorithms developed to project the degree of impact associated with construction and operation of a dredged material site at that location. Details, formulas, and discussions of algorithms are provided in the following sections of this chapter. In all cases, algorithms were developed so that high scores represented high impact and low scores represented low impact.

Scores for each environmental concern were normalized to range between zero and 10 using the formula:

$$\text{Normalized Score} = \frac{\text{Site Score - Minimum score for all sites}}{\text{Range of scores for all sites}} * 10$$

Table 3-3. Summary of land use/land cover data (in acres) for alternative sites. Asterisks indicate existing disposal sites.

Alternative Sites	Habitat (Land Use/Land Cover) Category																
	Existing Disposal Area	Upland Habitat	Fresh-water Wetland	Ponds, Borrow Pits, etc.	Mixed Elevation Marsh	High Elevation Marsh	Low Elevation Marsh	Tidal Flats	Small Tidal Creek	Large Tidal Creek	Shallow Estuary	Deep Estuary	Coastal Dunes & Beaches	Shallow Coastal Water	Deep Coastal Water	Live Bottom Habitat	Off Shore Berm	Total Acres
Yellow House Creek Alt 1*	617	5			322				24									968
Yellow House Creek Alt 2*	617	5																622
Yellow House Creek Alt 3*					322				24									346
Rodent Island - Alt 2		182	1	1	18	41	39		0	4								286
Rodent Island - Alt 2		210	1	1	23	57	52		0	4								348
T C Depot Site*	53	21			102													176
Naval Weapons Center Site*	299	4	3		1													307
Upper Thomas Island		57			196				0	4								257
Clouter Creek Site*	1502	26			6													1534
Lower Thomas Island		212	2		11													225
Old Landfill Site*	149	15			1													165
Drum Island*	220																	222
Patriots Point Site*	49																	49
Middle Shoal		1					1					234	3					239
Fort Johnson Site*	5	2		5	186			22			0	7	7					259
Morris Island - Alt 1*	558	22			4			1					48	247				880
Morris Island - Alt 2*	558	24			4			1					79	559				1225
Morris Island - Alt 3*	558	22			4		1											385
Cainhoy Road Site - Alt 1		576	29			7	6											618
Cainhoy Road Site - Alt 2		621	43			7	6											677
Point Hope Island Site - Alt 1		583	46	1		18	29											677
Point Hope Island Site - Alt 2		604	46	1		34	88		8									781
Parkers Island Site - Alt 1		450	99			14	1											564
Parkers Island Site - Alt 2		458	99			31	1											589
Town Creek Site	5		3		12							101						121
Daniel Island Site*	677	8								0								685
ODMDS - Alt 1*															8367	1476		9843
ODMDS - Alt 2*															3060	156		3216
Offshore Berm														460		5		465
Totals																		

Table 3-4. Summary of land use/land cover data (in acres) for acres adjacent to alternative sites. Asterisks indicate existing disposal sites

Alternative Sites	Habitat (Land Use/Land Cover) Category																
	Existing Disposal Area	Upland Habitat	Fresh-water Wetland	Ponds, Borrow Pits, etc.	Mixed Elevation Marsh	High Elevation Marsh	Low Elevation Marsh	Tidal Flats	Small Tidal Creek	Large Tidal Creek	Shallow Estuary	Deep Estuary	Coastal Dunes & Beaches	Shallow Coastal Water	Deep Coastal Water	Live Bottom Habitat	Off Shore Berm	Total Acres
Yellow House Creek Alt1*	22	12			144					315								493
Yellow House Creek Alt2*		8			94					111								213
Yellow House Creek Alt3*	22	4			50					204								280
Rodent Island - Alt 1		33			1	37	301		19	69								460
Rodent Island - Alt 2		19			0	27	326		20	85								477
T C Depot Site*	7	114		3	35					57								216
Naval Weapons Center Site*	18	86	50		64				4	48								270
Upper Thomas Island	25	137	1		91					53								307
Clouter Creek Site*	29	14			249					359								651
Lower Thomas Island		102	3		111				9									225
Old Landfill Site*	7	52			96				5			51						211
Drum Island*	11				57							204						272
Patriots Point Site*	10	77			16							19						122
Middle Shoal							13					211	1					225
Fort Johnson Site*				1	98						44	81	7					231
Morris Island - Alt 1*	22	44			105			31			48		24	182				456
Morris Island - Alt 2*	22	43			113			31			49		40	275				573
Morris Island - Alt 3*	22	44			105			31			48		30	40				319
Cainhoy Road Site - Alt 1		259	35	8		43	59		6									353
Cainhoy Road Site - Alt 2		217	19	8		43	60		6									410
Point Hope Island Site - Alt 1		94	4			73	242		25	57								495
Point Hope Island Site - Alt 2		74	4			60	192		19	57								406
Parkers Island Site - Alt 1		135	15			164	127	6	12	11								470
Parkers Island Site - Alt 2		128	15			147	127	6	12	11								446
Town Creek Site	119		2		14				0			51						186
Daniel Island Site*	22	118			20					232								392
ODMDS - Alt 1*															6146	1085		7231
ODMDS - Alt 2*															3925	206		4131
Offshore Berm														2862			30	2892
Totals																		

Table 3-5. Summary of Florida Land Use, Cover, and Forms Classification System (FLUCCS) categories that were combined for this study.

RIH Category		
Upland	110:	Resid., low density (<2 dwellings/AC)
Upland	120:	Resid., med. density (2-5 dwellings/AC)
Upland	140:	Commercial and services
Upland	155:	Other light industrial
	188:	Historical Site
Upland	190:	Open land
Upland	210:	Cropland and pastureland
Upland	310:	Herbaceous rangeland
Upland	322:	Coastal shrub rangeland
Upland	330:	Mixed rangeland
Upland	411:	Pine flatwoods
Upland	434:	hardwood-conifer mixed
Upland	440:	Tree plantation
Upland	741:	Rural land in transition w/out pos. indicators of intended activity
Upland	815:	Port facilities
Upland	832:	Electrical power facilities
Existing Contained Disposal Area	743:	Spoil area
Ponds, Borrow Pits, & Impoundments	524:	Lake <10 acres
Ponds, Borrow Pits, & Impoundments	530:	Reservoirs
Ponds, Borrow Pits, & Impoundments	534:	Reservoirs <10 acres
Freshwater wetland	615:	Stream and lake swamp (bottomland)
Freshwater wetland	630:	Wetland forested mixed
Freshwater wetland	641:	Freshwater marsh
Mixed Elevation Marsh	642:	Saltwater marsh
Low Elevation Marsh	6421:	Cordgrass salt marsh
High Elevation Marsh	6422:	Needlerush salt marsh
Tidal Sand and Mud Flats	651:	Tidal flats
Beaches and Dunes	710:	Beaches other than swimming beaches

Table 3-6. Proposed analysis scheme. Algorithms to calculate scores in the matrix are presented in the remaining sections of this chapter.

Evaluation Criteria	Alternative Sites											Weighting Factor
	1	2	3	4	5	6	7	8	9	...	24	
Existing Environmental Quality	10.00	8.75	5.00	7.50	5.00	7.50	1.00	1.00	8.75	...	1.00	1
Discharge Impacts on Water Quality	8.25	4.25	5.17	8.67	5.15	10.00	0	0.25	3.25	...	7.00	1
Loss of Critical Habitat	8.00	10.00	7.25	7.36	6.75	7.15	2.95	0	3.0	...	9.95	1
Impacts on Adjacent Habitat	10.00	9.25	5.25	4.15	6.25	7.25	0	0	1.55	...	9.10	1
Impacts on Material Cycles	10.00	8.70	9.15	3.15	5.50	8.65	0	1.15	1.55	...	9.25	1
Impacts on Migration and Movement	10.00	6.00	6.00	10.00	6.00	3.00	0	0	0	...	10.00	1
Impacts on Human Uses	8.00	6.75	8.15	8.24	5.51	0	0	3.15	2.15	...	10.00	1
Impacts on Groundwater Quality	6.00	5.50	8.20	3.25	2.10	10.00	4.15	5.15	3.25	...	0	1
Impacts on Cultured Resources	10.00	5.20	1.00	1.00	0	0	0	0	3.12	...	9.25	1
Cumulative Environmental Impact (Σ)	80.25	64.40	55.17	53.32	42.26	53.55	8.10	10.70	26.62	...	65.55	
Capacity (10^6 cu yds)	50	10	40	25	35	20	2	150	50	...	100	
Capacity Adjusted Score (score/10^6cu yd)	1.61	6.44	1.38	2.13	1.21	2.68	4.05	0.07	0.53	...	0.66	
Normalized Cumulative Environmental Impact	10.0	7.80	6.52	6.27	4.74	6.30	0	0.36	2.57	...	7.96	
Normalized Capacity Adjusted Score	2.42	10.0	2.06	3.23	1.79	4.10	6.25	0	0.72	...	0.93	
Sum Normalized Cumulative Impact and Capacity Adjusted Score	12.42	17.80	8.58	9.50	6.52	10.40	6.25	0.36	3.29	...	8.89	
Rank Order for Final Assessment	9	10	5	7	4	8	3	1	2	...	6	

The normalization process ensured that the relative scores for each environmental concern were equally weighted. However, it may be desirable to weight some environmental concerns more than others. The ability to differentially weight scores was incorporated into the analysis scheme as a series of weighting factors shown in the far right column of Table 3-6. Cumulative environmental impacts were estimated by summing down the columns in Table 3-6 (i.e., across environmental concerns).

Alternative sites differ in dredged material disposal capacity by over two orders of magnitude (Table 3-1). Large capacity sites will generally have a larger cumulative environmental impact than small capacity sites but offer a smaller impact per unit volume of disposal capacity. Therefore, before sites are contrasted to identify alternatives that represent the least long-term threat to environmental resources consideration should be given to among site differences in disposal capacity. Consideration for among-site differences in capacity was accomplished by dividing the estimate of cumulative environmental impact (i.e., row 11 in Table 3-6) by site disposal capacity. The value that results is a relative measure of the environmental impact (i.e., environmental costs) per cubic yard of disposal capacity (i.e., benefits). This analytical endpoint is analogous to the engineering/economic assessment endpoint developed for alternative sites by the USACOE (i.e., dollars/cubic yard).

Alternatives that have both relatively small cumulative environmental impacts and small environmental costs per cubic yard of disposal capacity are the ones which represent the least long-term threat to environmental resources. These sites were identified by equally weighting scores for cumulative environmental impact and environmental impact per cubic yard of disposal capacity and summing the equally weighted scores to obtain line 16 in Table 3-6. This value represents the best projection of the long-term threat of each alternative to environmental resources. Figure 3-2 shows the relationship between the areal extent of alternatives and disposal capacity. Based on this figure, it is clear that disposal capacity is not associated with the areal extent of ocean disposal alternatives (e.g., ODMDS alternatives 1 & 2, Folly Beach Berm). This is because the amount of dredged material that is likely to be placed at ocean disposal sites is a function of many factors other than size such as currents, depth, and the physical and chemical characteristics of the material. Disposal capacity is, however, relatively strongly related to the areal extent of alternatives for non-ocean alternatives (r^2=0.90).

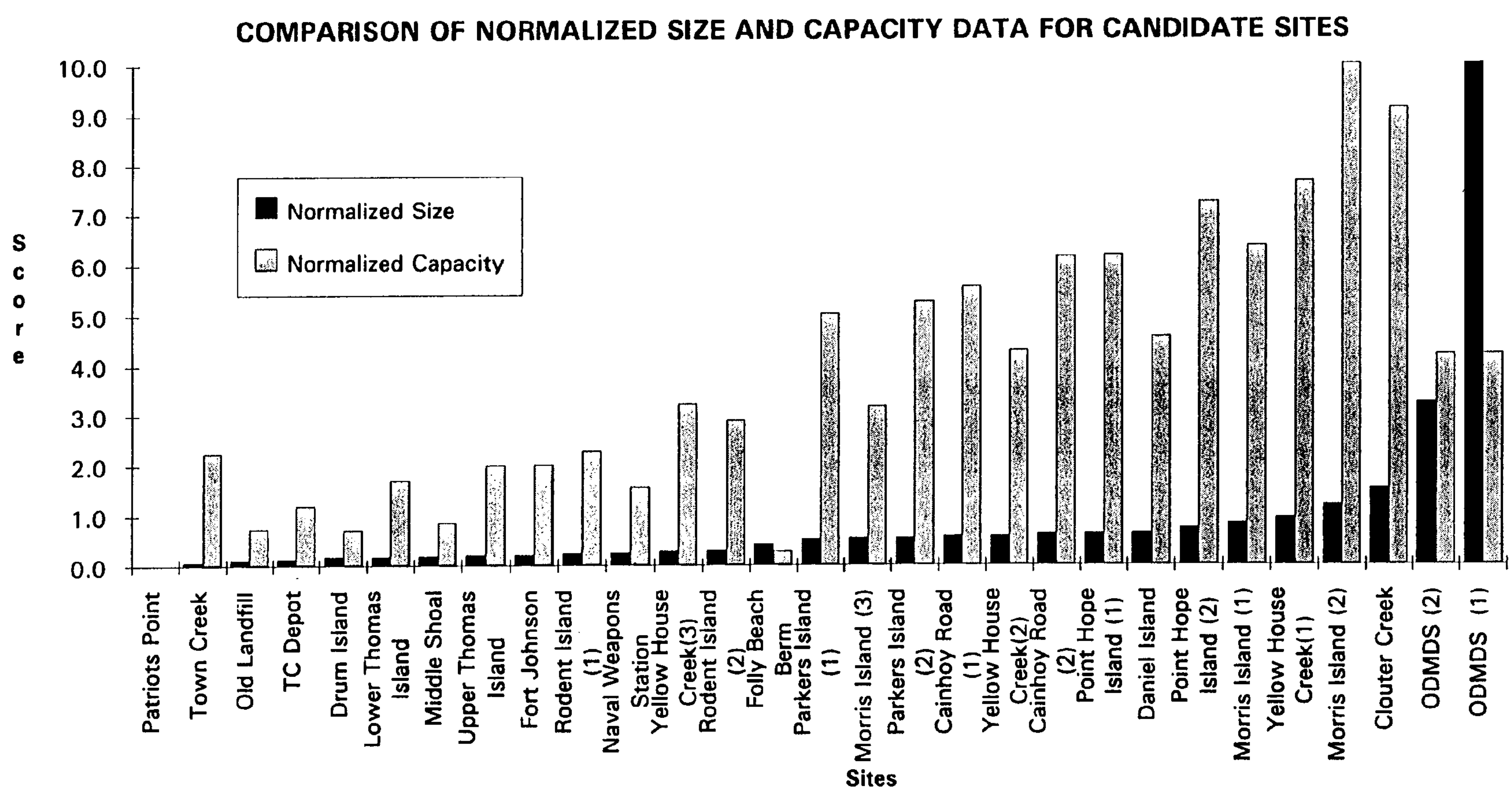


Figure 3-2. Comparison of normalized size (acres) and normalized disposal capacity data (cubic yards) for alternatives.

E. Task 5: Conduct of Analyses

1. Assessment of Impacts on Existing Environmental Quality

The purpose of this criterion was to ensure that alternative sites which were located in areas having good environmental quality were scored high (i.e., were projected to have large impact) relative to sites which were located in areas having low to marginal environmental quality. The indicator selected for defining existing environmental quality was water quality standards promulgated by the South Carolina Department of Health and Environmental Control (DHEC). State water quality standards consist of numeric and narrative criteria (i.e., limits on pollution) designed to prevent degradation, protect designated uses (e.g., swimming, fishing, shellfish harvesting), and maintain indigenous fish, shellfish, and wildlife populations (SCDHEC 1990). When promulgating standards and criteria, DHEC considered:

- Physical and chemical characteristics (e.g., size, depth, surface area, volume, hydrodynamics) of the waterbody,
- The character of bordering lands and its suitability for supporting designated uses,
- Present, past, and projected uses of the water body and adjoining lands, and
- The present quality of the water body.

Because state water quality standards and criteria are based on a general understanding of the physical, chemical, and biological characteristics of a water body as well as present, past, and projected future uses, they are a good indicator of existing environmental quality. EPA assesses the quality of the nation's waters by estimating the proportion of its waterbodies that meet state standards and designated uses (e.g., USEPA 1990).

The procedure used to project impact on existing environmental quality consisted of the following:

- Determine the existing DHEC water quality classification for each site.
- Score each site using the categorical scoring scheme shown in Table 3-7.

Table 3-7. Scorings scheme used for projecting impact on existing environmental quality

DHEC Classification	Score
SFH	10
SFH/Restricted	7
SA	4
SB	1

Alternatives with excellent water quality were scored 10, and alternatives with poor water quality were scored 1. This approach assumes that siting a dredged material disposal facility in a location characterized by good water quality has a higher potential for causing environmental harm than siting the same facility in an area characterized by poor water quality. If sites had multiple water quality classifications (e.g., Parkers Island has both an SFH and SFH/restricted classification) the average score for the multiple classifications was used.

Figure 3-3 is a summary of the site specific scores for projected impact on existing environmental quality. Sites located in the Cooper River and lower Charleston Harbor generally were projected to have low potential for impacting existing environmental quality. Sites in the Wando River, near Clark Sound, and the Atlantic Ocean were projected to have a relatively high potential for adversely affecting existing environmental quality.

2. Projected Impacts on Water Quality of Receiving Water Body

The purpose of this criterion was to identify alternative sites which were projected to have large impacts on the water quality and score them high relative to sites that were projected to have small impacts on water quality. The indicator used to project impact on water quality was:

$$\text{Projected Water Quality Impacts} = C_i + \sum_{j=1}^{16}(A_j * S_j) \quad (1)$$

where:

C_i = Estimated capacity (cu yds) for the ith alternative.

i = 1-29 representing the alternative configurations evaluated.

A_j = Area of jth Representative Important Habitats (RIHs) that would be susceptible to water quality impact in a 200-m wide buffer zone around non-ocean and 1000-m buffer around alternative ocean disposal sites.

S_j = Categorical variable ranging from 0 (not susceptible) to 3 (very susceptible) representing the relative susceptibility of the jth RIH to water quality impacts.

j = 1-16 representing the RIHs included in the assessment.

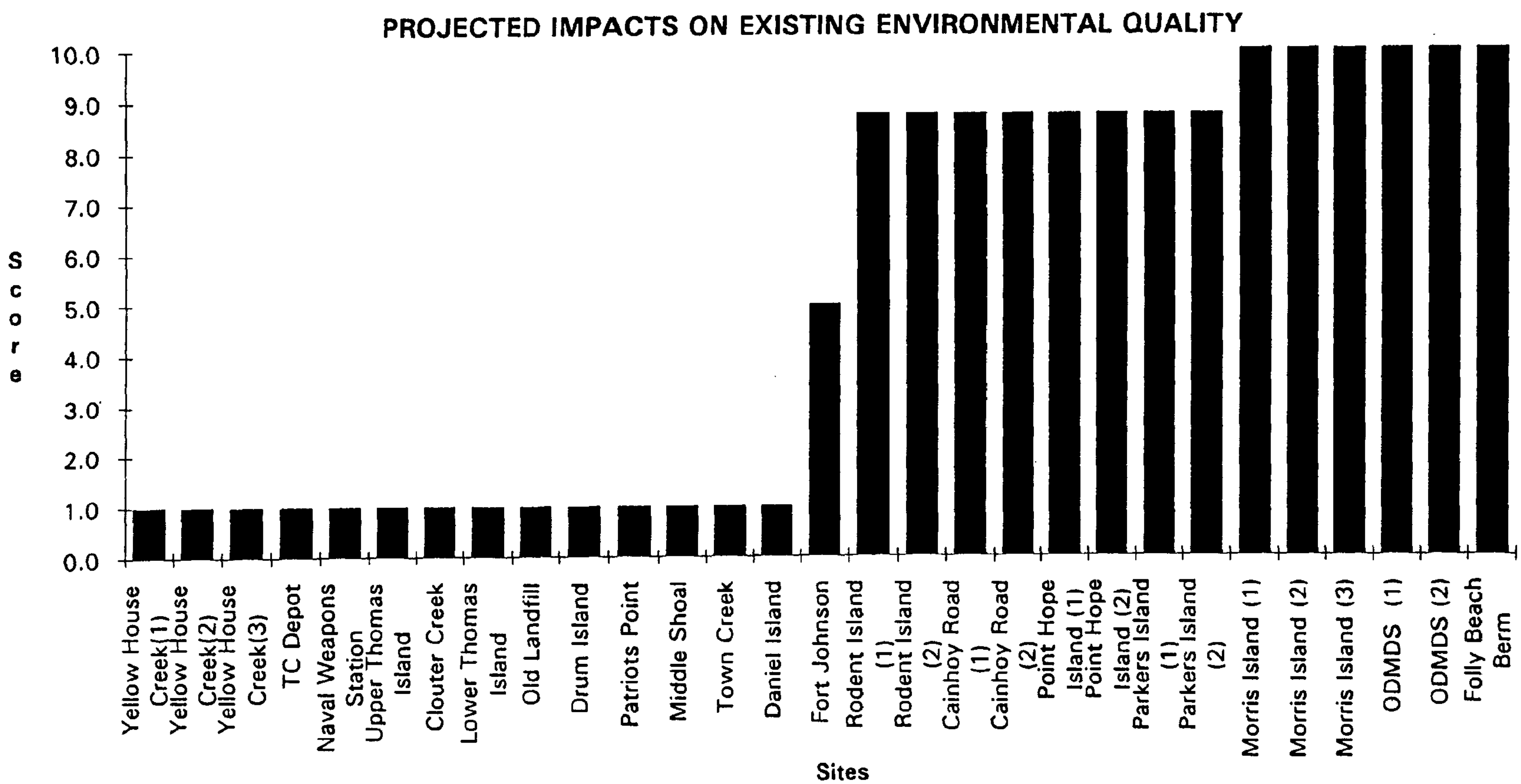


Figure 3-3. Projected impact on existing environmental quality.

Water quality impacts from dredged material disposal facilities are a function of: (1) the physical/chemical characteristics of effluents, (2) the mixing/flushing capacity of receiving waters, (3) the amount (i.e., volume) of discharge, and (4) the susceptibility of adjacent habitats to effluents. The physical/chemical characteristics of effluents is a function of the kinds of material that will be placed at a site. Data on the kinds of material that would be disposed of at each site were not available for this analysis. The kind of material and the physical/chemical characteristics of effluents was therefore assumed to be similar for all alternatives. Tidal currents at candidate sites are large (mean tidal range 1.6 m, spring tides average 1.9 m) and approximately equivalent (Davis and Van Dolah, 1992). Therefore, site specific differences in mixing were assumed to be negligible. Because the physical/chemical characteristics of effluents and mixing characteristics for candidate sites were assumed to be similar across sites, terms for these factors were not included in equation 1. These factors were, in effect, constants.

The indicator used for discharge volume was the estimate of disposal capacity provided by the USACOE (term C in equation 1). Use of this indicator assumed the larger the capacity, the greater the discharge volume. The indicator used to represent the susceptibility of the adjacent environment to water quality impacts was the type and amount of habitat adjacent to each alternative site (term A in equation 1) multiplied by the projected relative susceptibility of each RIH to effluents (term S in equation 1).

The procedure used to score sites to assess water quality impacts consisted of the following steps:

- Obtain an estimate of the areal extent of each RIH within 200 m of each non-ocean and 1000 m of each ocean alternative from Table 3-3 (i.e., term A in equation 1).

- Determine the relative susceptibility of each RIH to assimilate effluents (term S in equation 1). Information in the scientific literature, discussions at the regional workshop, and experience of the scientific staff working on the project provided the basis for these determinations. Table 3-8 lists the values of S used.

- Multiply the estimates of areal extent for each RIH by their relative susceptibility and sum across all RIHs. Normalize summed products to a scale of 0-5.

Table 3-8. Values of relative susceptibility for RIH's to assimilate discharges from a dredged material disposal facility.

Habitat Type	Susceptibility Index	Alternate Susceptibility Index
Existing Disposal Area	0	
Upland Habitat	0	
Freshwater Wetlands	1	3
Ponds, Borrow Pits & Impoundments	2	
Mixed Estuarine Wetlands	1	3
High Elevation Estuarine Wetlands	1	3
Low Elevation Estuarine Wetlands	1	3
Tidal Flats	3	
Small Tidal Creeks	3	
Large Tidal Creeks	2	
Shallow Estuary	3	
Deep Estuary	1	3
Coastal Dunes and Beaches	0	
Shallow Coastal Waters	1	3
Deep Coastal Waters	1	3
Live Bottom	3	1

- Obtain estimates of site capacity from Table 3-1. Capacity estimates considered the dewatering potential of sites. Normalize capacity estimates to a scale of 0-5.

- Calculate site scores using equation 1.

- Normalize scores to a scale of 0-10 using the procedure discussed in the overview of analysis methods (Section D).

- Determine the rank order of alternatives.

Sites projected to have the greatest impacts on water quality were alternatives with large capacity (i.e., large volumes of effluent) including Clouter Creek, Yellow House Creek, Morris Island - alternatives 1 and 2, and Point Hope Island alternatives (Figure 3-4). These sites frequently had large amounts of adjacent habitats that were sensitive to effluents from dredged material disposal facilities. Alternatives projected to have relatively small impacts on the water quality were Patriots Point, Middle Shoal, Drum Island, Old Landfill, Folly Beach Berm, Town Creek, and TC Depot (Figure 3-4). These sites generally had small capacity and small amounts of the habitats adjacent to them which were sensitive to effluents from dredged material disposal facilities.

Sensitivity analyses were conducted to evaluate the influence that changes in susceptibility index values (term S in equation 1) had on normalized scores and the rank order of alternatives. For these analyses, the alternate susceptibility index values in Table 3-8 were used and scores and rank order recalculated. These analyses indicated that applying alternate susceptibility values resulted in only small changes in scores and rank order.

3. Projected Impacts of Critical Habitat Loss

The purpose of this criterion was to identify candidate sites that were projected to result in losses of large amounts of habitat that have important roles in the life cycle of biota (e.g., nursery areas) and score them high. Alternatives that were projected to result in losses of small amounts of critical habitat for biota were scored low. The indicator used to project impacts on critical habitat was:

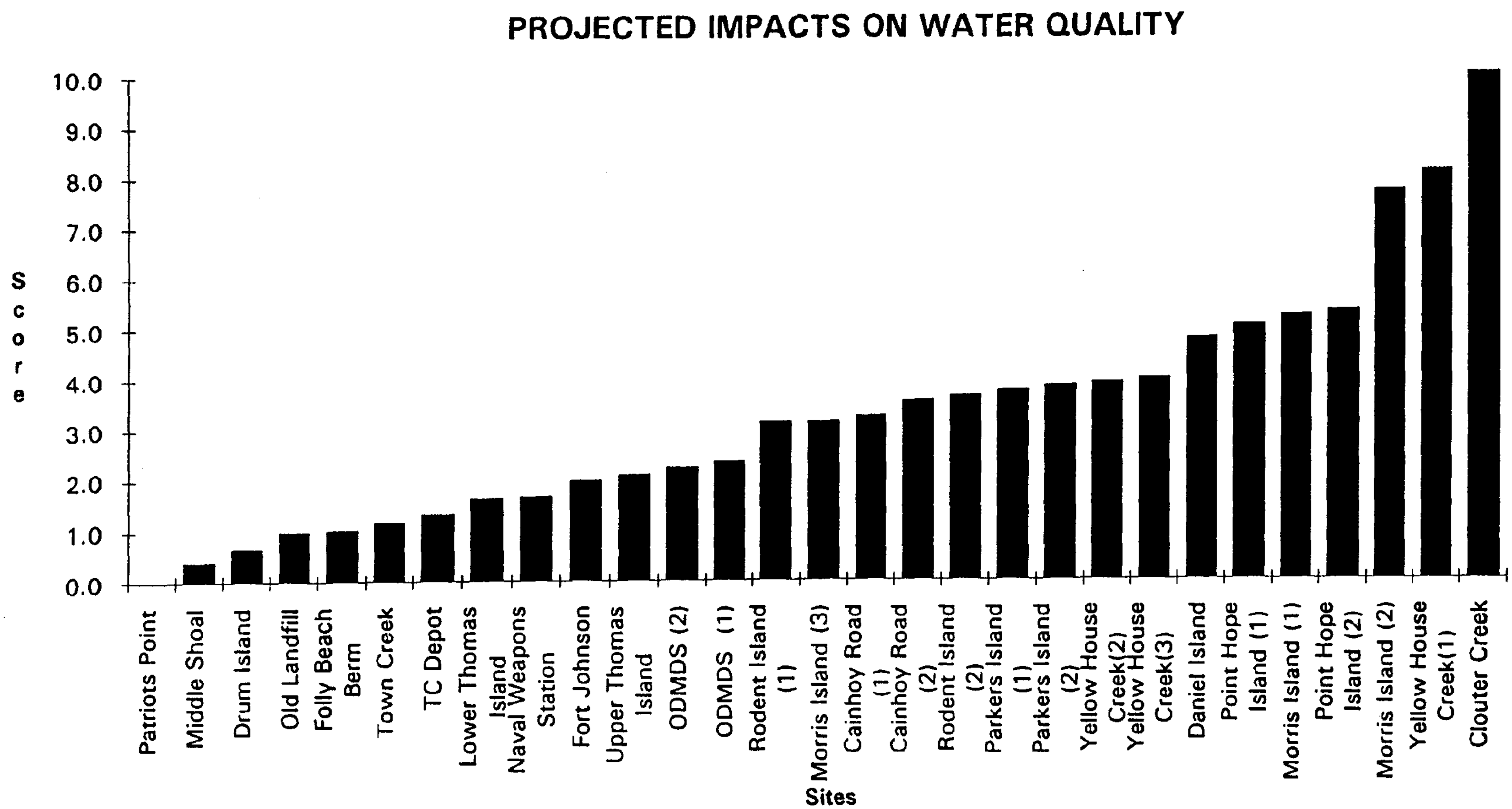


Figure 3-4. Projected impacts on water quality.

$$\text{Projected Critical Habitat Loss} = \sum_{i=1}^{16} (A_i * V_i) \qquad (2)$$

where:

A_i = Area of the ith Representative Important Habitat (RIH) for alternative disposal sites.

V_i = Categorical variable ranging from 0 (low value) to 3 (high value) representing the relative importance of the ith RIH to ecological requirements of RIB.

i = 1-16 represented the RIHs included in the assessment.

The consequences of habitat loss to RIB populations are a function of: (1) the amount (i.e., acreage) of the loss, (2) the type of habitat loss, and (3) the importance of the habitat to ecological processes (e.g., reproduction). All of these factors were incorporated into equation 2.

The procedure used to calculate scores for assessing the consequences of critical habitat losses consisted of the following steps:

- Obtain an estimate of the areal extent of RIH losses (i.e., term A in equation 2) for each site from Table 3-3.

- Estimate the relative value of each RIH to processes influencing the life cycle and abundance of RIB (i.e., term V in equation 2). Information in the scientific literature, discussions at the regional workshop, and the experience of the scientific staff working on the project were used to develop these estimates. Table 3-9 lists the values of V used.

- Calculate site scores using equation 2.

- Normalize scores to a scale of 0-10 using procedure discussed in the overview of analytical methods (Section D).

- Because the initial scores calculated from equation 2 were skewed with the majority of values ranging between 0-1 (Figure 3-5), a natural logarithm transformation [i.e., transformed value = ln (x+1)] was performed to reduce skewness and provide a wider spread of scores for alternatives. It is apparent from Figure 3-5 that the transformation improved separation for alternatives

Table 3-9. Values used for relative importance of RIH's to ecological processes affecting the life cycle and abundance of RIB.

Habitat Type	Importance Index	Alternate Importance Index
Existing Disposal Area	0	
Upland Habitat	1	3
Freshwater Wetlands	3	1
Ponds, Borrow Pits & Impoundments	2	1
Mixed Estuarine Wetlands	3	1-2
High Elevation Estuarine Wetlands	3	1-2
Low Elevation Estuarine Wetlands	3	1-2
Tidal Flats	3	1
Small Tidal Creeks	3	
Large Tidal Creeks	3	1
Shallow Estuary	3	
Deep Estuary	2	
Coastal Dunes and Beaches	2	
Shallow Coastal Waters	1	3
Deep Coastal Waters	1	
Live Bottom	3	1

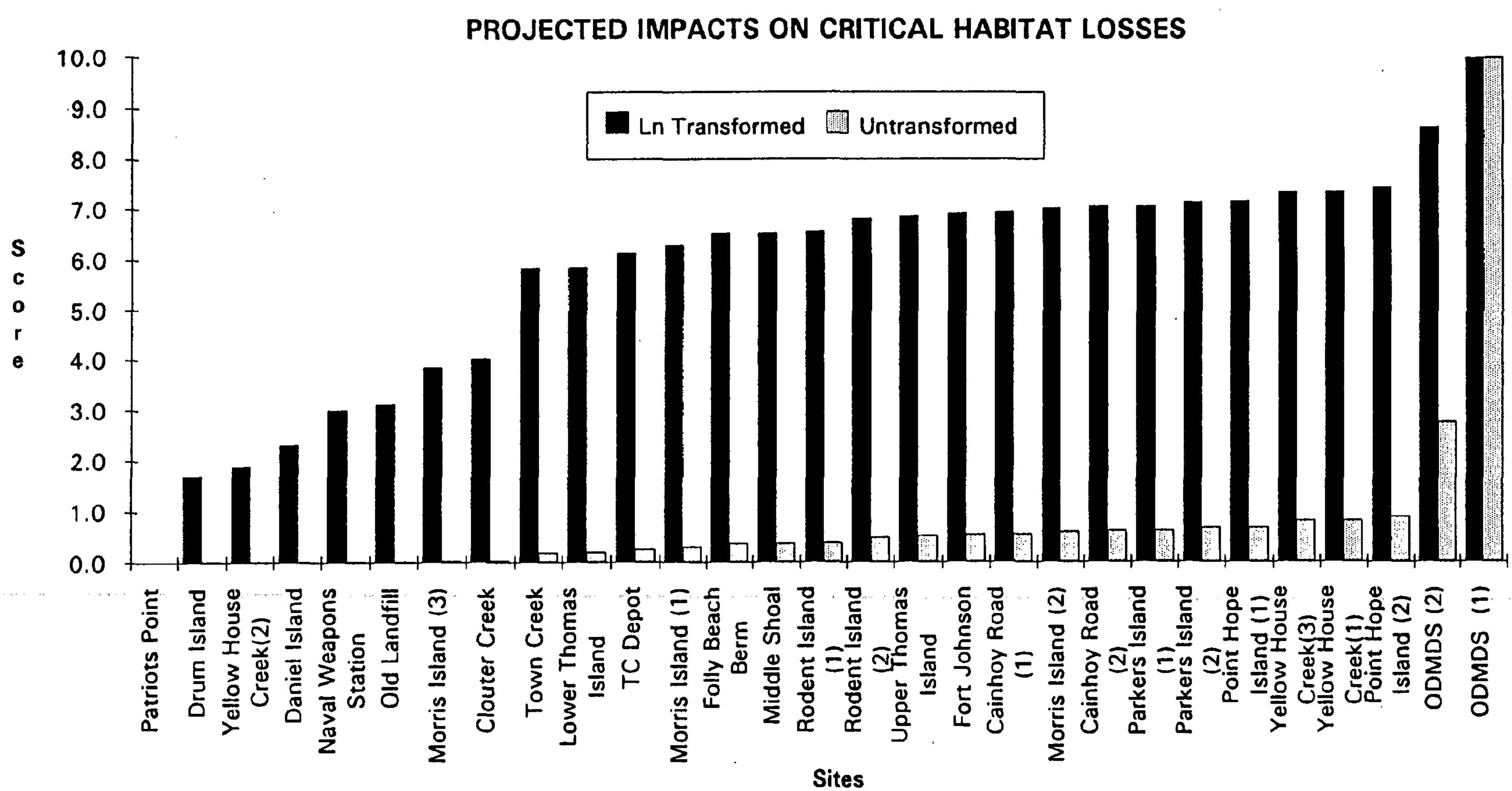


Figure 3-5. **Projected impacts on critical habitat loss.**

projected to have small impacts. This transformation, however, had no effect on the overall relationship among alternatives. The skewness resulted because ocean disposal alternatives were several orders of magnitude larger than non-ocean alternatives (Table 3-3).

- Determine the rank order of alternatives.

Scores for the indicator of critical habitat loss projected most existing and historically used disposal sites including Patriots Point, Drum Island, Yellow House Creek alternative 2, Daniel Island, Naval Weapons Station, Old Landfill, Morris Island alternatives, and Clouter Creek would have relatively small impacts to RIB (Figure 3-5). Critical habitat losses resulting from remaining alternatives were projected to be relatively large.

Sensitivity analyses were conducted to evaluate the influence that relative importance values assigned to RIHs (i.e., term V in equation 2) had on normalized scores and rank order. For these analyses, relative importance values for RIHs were changed to the alternative values shown in Table 3-9, and scores and rank order recalculated. These analyses indicated that changes to relative importance values had little influence on the magnitude of normalized scores or rank order for alternatives. Figure 3-6 illustrates the effects of setting the relative importance value for salt marsh habitat types equal to 1 (a low value) vs 3 (a high value) used for the nominal analysis (i.e., standard run). The negligible effect of this change is obvious. Correlation coefficients between scores and rank order for the nominal analysis and scores obtained using the alternative relative importance values in Table 3-9 ranged between 0.99 and 0.97.

Areal extent was only weakly associated with projected impacts on critical habitat loss (r^2=0.20). Figure 3-7 compares the standard run scores to those generated by setting all RIH values equal to the same values. Equalizing all site scores is equivalent to ranking alternatives based on areal extent and normalizing ranks between 0 and 10. This analysis demonstrates the relatively small effect areal extent had on analysis results.

4. Projected Impacts to Adjacent Habitats

The purpose of this criterion was to identify sites that had adjacent habitats that were vulnerable to construction and operation of dredged material disposal sites and give them high

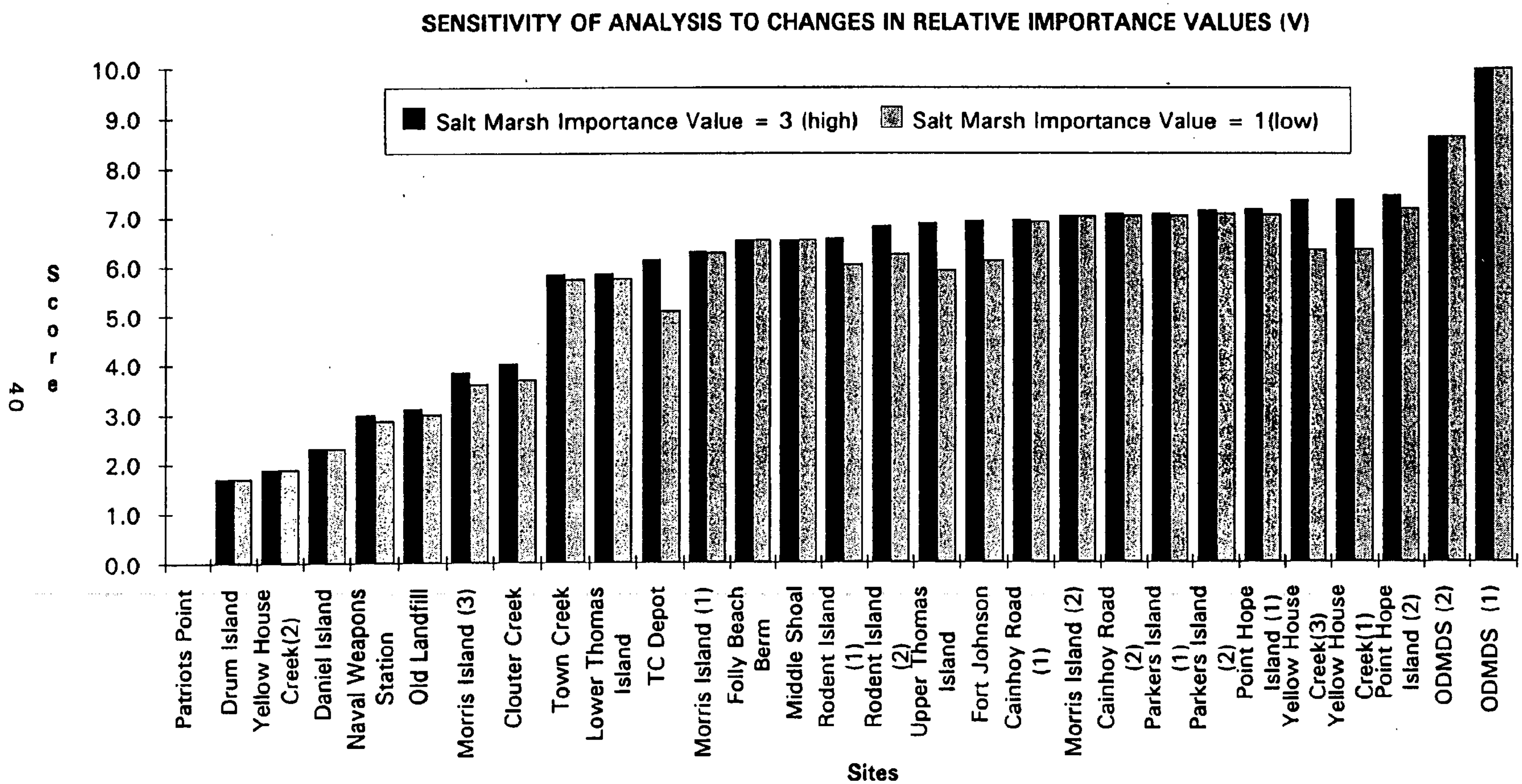


Figure 3-6. Effect of assigning a low relative importance value to saltmarsh habitats to the estimate of impact on critical habitat losses.

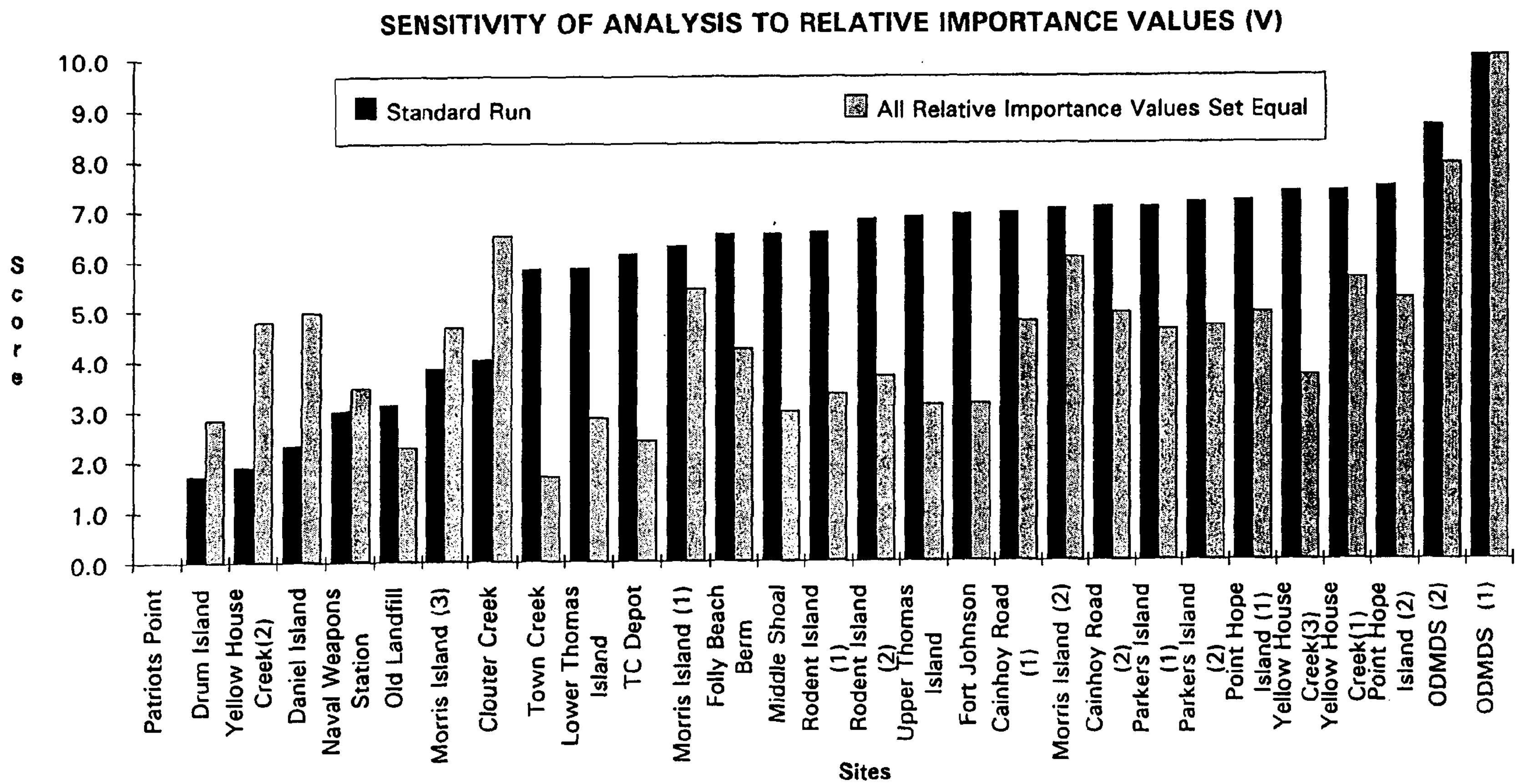


Figure 3-7. **Effect of using the same relative importance value (S) for all habitats in the estimate of impact on critical habitat loss.**

values. Alternatives that had adjacent habitats that were not sensitive to activities associated with construction and operation of dredged material disposal sites were given low scores. The indicator used to project relative impact on adjacent habitats was:

$$\text{Projected Impacts on Adjacent Habitats} = \sum_{i=1}^{16} (A_i * S_i) \qquad (3)$$

where:

A_i = Area of Representative Important Habitat (RIH) within a 200-m wide buffer zone around non-ocean and 1000-m buffer zone around ocean candidate disposal sites.

S_i = Categorical variable ranging from 0 (low value) to 3 (high value) representing the relative susceptibility of the ith RIH to construction and operations of a dredged material disposal facility.

i = 1-16 representing the RIHs included in the assessment.

The environmental consequences of construction and operation of a dredged material disposal facility on the adjacent environment is a function of: (1) the amount and type of habitat that exists in adjacent environments, and (2) the sensitivity of the different types of habitat present to perturbations associated with construction and operation of dredged material disposal facilities. All of these factors were incorporated in equation 3.

The procedure used to calculate site scores consisted of the following steps:

- Obtain an estimate of the areal extent for each RIH within 200-m of non-ocean and 1000-m of ocean alternatives (i.e., term A in equation 3) using data in Table 3-4.
- Estimate the relative sensitivity of each RIH to activities associated with construction and operation of a dredged material disposal facility (i.e, term S in equation 3). Information in the scientific literature, discussions at the regional workshop, and the experience of the scientific staff working on the project provided the basis for development of these estimates. Table 3-10 lists the values of S used.
- Calculate site scores using equation 3.
- Normalize scores to a scale of 0-10 using the procedures

Table 3-10. Values used for relative sensitivity of adjacent habitats to construction and operation of dredged material disposal facilities.		
Habitat Type	Relative Value Used	Alternate Value Used
Existing Disposal Area	0	
Upland Habitat	1	
Freshwater Wetlands	2	
Ponds, Borrow Pits & Impoundments	3	1
Mixed Estuarine Wetlands	1	3
High Elevation Estuarine Wetlands	1	3
Low Elevation Estuarine Wetlands	1	3
Tidal Flats	1	3
Small Tidal Creeks	3	
Large Tidal Creeks	3	1
Shallow Estuary	3	1
Deep Estuary	2	
Coastal Dunes and Beaches	1	
Shallow Coastal Waters	1	3
Deep Coastal Waters	1	
Live Bottom	3	

discussed in the overview of analysis methods (Section D).

- Because the initial scores calculated from equation 3 were skewed to smaller values, a natural logarithm transformation was used to reduce skewness and provide a more even distribution (i.e., wider spread) for projected scores. This transformation did not alter relationships among alternatives and improved discrimination among alternatives projected to have small impacts. The skewness resulted because the size of the adjacent environment for ocean disposal alternatives was several orders of magnitude larger than that for alternatives located in terrestrial or estuarine (i.e., non-ocean) environments (Table 3-4).

- Determine the rank order of alternatives.

The decision to constrain projections of potential impacts on adjacent environment for non-ocean candidate sites to a 200-m wide buffer zone was based on the following information:

- Adverse effects from construction and operation of diked dredged material disposal facilities are based on the experience of the Authors and are generally not visable beyond about 200 m for dredged material disposal facilities in Charleston Harbor.

- The distribution of habitat types within 200 m of each site was generally similar to (i.e., representative of) habitat distributions in the region. Therefore, conclusions reached for a 200-m buffer zone were assumed to be proportional to conclusions that would have resulted had a larger or smaller buffer zone been used for analysis.

The basis for the 1000-m buffer zone used for ocean disposal alternatives was:

- Dredged material deposited in uncontained open-water oceanic disposal sites have the potential to be dispersed over large distances (i.e., hundreds to thousands of meters).

- Some of the habitats characteristic of areas adjacent to proposed open-water ocean disposal alternatives (i.e., live bottom habitats) are thought to be intolerant to alterations to suspended sediment concentrations and exposure to toxic contaminants at relatively low concentrations.

Alternatives projected to have small impacts on adjacent habitats were small sites that had small buffer zones associated with them such as Town Creek, Patriots Point, Lower Thomas Island, Old Landfill, and TC Depot (Figure 3-8). The size of the buffer zone for these sites was usually less than 300 acres (Table 3-4). In addition, habitats adjacent to these sites were predominately estuarine wetlands or uplands. These RIHs are relatively tolerant to adverse effects associated with construction and operation of dredged material disposal sites. Sites projected to have large impacts upon adjacent habitats were ocean disposal sites, including ODMDS alternatives and the Folly Beach Berm, or large diked sites located along large tidal creeks including Clouter Creek, Yellow House Creek alternatives 1 and 3, Daniel Island, Rodent Island alternatives, and Point Hope Island alternatives (Figure 3-8). The areal extent of large tidal creeks occurring in adjacent environments was strongly associated with scores for projected impacts on adjacent environments ($r^2=0.67$). This was because large tidal creeks were projected to be sensitive to construction and operation of dredged material disposal facilities (i.e., term S in equation 3 for large tidal creeks was set equal to 3), and the area of large tidal creeks in the environment adjacent to several large diked non-ocean sites was substantial.

Sensitivity analyses were conducted to evaluate the influence that changes in relative susceptibility values for RIHs (i.e., term S in equation 3) had on normalized alternative scores and rank order for projected impact on adjacent habitats. For these analyses, relative susceptibility values for RIHs were changed to the alternative values shown in Table 3-10, and scores and rank orders recalculated. These analyses suggested that changes in relative susceptibility values had little influence on normalized scores or rank order. The change in S that had the most effect was a shift in the susceptibility value for large tidal creeks from 3 (the high value used for the nominal run) to 1 (a low value) (Figure 3-9). This change resulted in modest shifts in the rank order and projected impacts for several alternatives, particularly Yellow House Creek alternatives, Daniel Island, and Clouter Creek. The general distribution of alternatives, however, remained similar.

5. Projected Impacts on Materials Cycles

The purpose of this criterion was to identify sites where construction and operation of a dredged material disposal facility

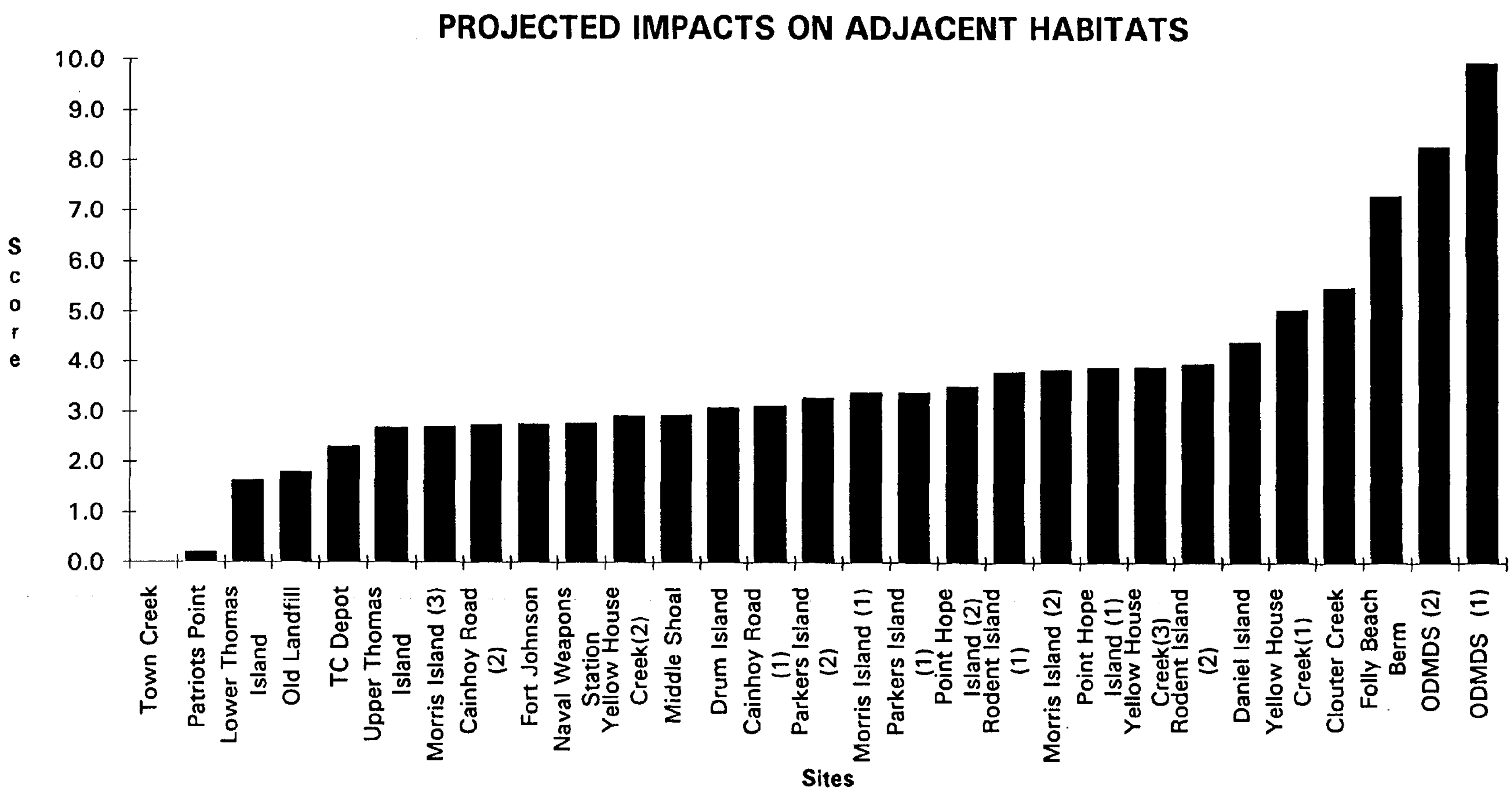


Figure 3-8. **Projected impacts on adjacent habitats.**

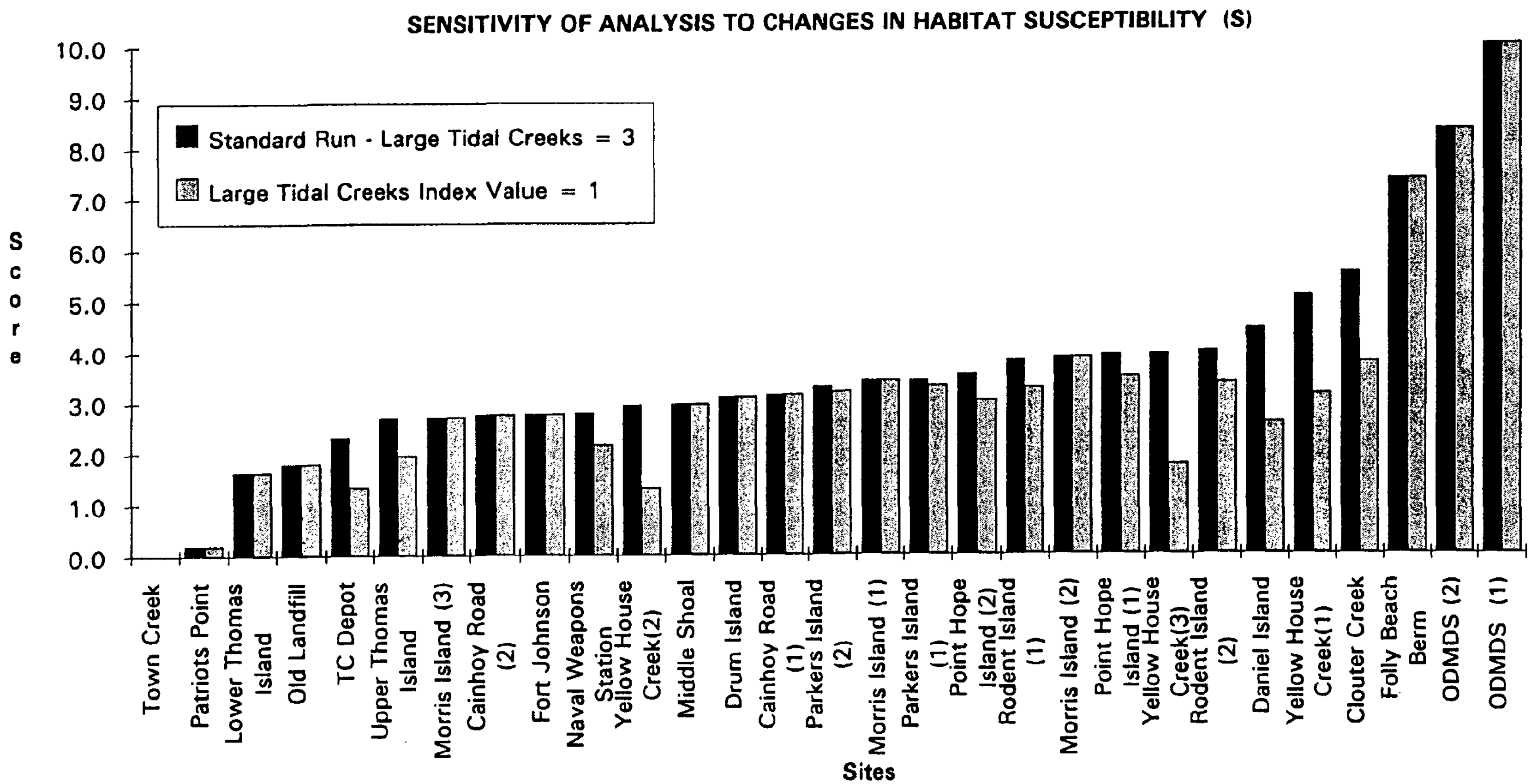


Figure 3-9. Effects of a low susceptibility (S) for large tidal creeks on projected impact on adjacent environments.

were projected to have relatively large impacts on material cycling processes and assign them high scores. Alternatives projected to have small impacts on material cycling processes were given low scores. Decreases in export of nitrogen and fine-grained sediments were selected as representative processes likely to be affected by construction and operation of a dredged material disposal facility (Beaulac and Reckhow 1982). The overwhelming importance of nitrogen and fine-grained sediments dynamics to the health of marine and estuarine ecosystems is well established (e.g., Nixon 1986, Nixon and Pilson 1983, Schubel and Carter 1984).

The indicator of the relative impacts on material cycling processes used was:

$$\text{Projected Impacts on Material Cycling} = B - D \qquad (4)$$

where:

B = Measure of the relative magnitude of nitrogen and sediment export before construction and operation of a dredged material disposal facility.

D = Measure of the relative magnitude of nitrogen and sediment export during and after operation of a dredged material disposal facility.

$$B = \sum_{i=1}^{16} (A_i * E_i) \qquad (5)$$

where:

A_i = Area of the ith Representative Important Habitat (RIH) at each alternative disposal site

E_i = Categorical variable ranging from 0 (low value) to 3 (high value) representing the relative magnitude of nitrogen and sediment export for the ith habitat.

i = 1-16 representing the RIHs included in the assessment.

$$D = \sum_{j=1}^{29} (A_j' * E') \qquad (6)$$

where:

A_j' = Area of jth proposed dredged material disposal alternative.

E′ = Constant representing the relative magnitude of sediment and nitrogen export for dredged material disposal sites from Table 3-11.

j = 1-29 representing the alternative configurations evaluated.

The impact of construction and operation of a dredged material disposal facility on material cycling processes is a function of: (1) the amount and type of habitat occurring at each site before construction, (2) the relative contribution of each habitat to nitrogen and fine-grained sediment export, (3) the size of the proposed dredged material disposal facility, and (4) the contribution of newly constructed dredged material disposal sites to nitrogen and fine-grained sediment export. For analyses in this report, the contribution of dredged material disposal facilities to nutrient and sediment cycles was assumed to be zero because these facilities are designed and operated to retain sediment particles and nutrients. Projected impacts on material cycling is the difference between conditions before construction and conditions during operation.

The procedure used to calculate scores for alternatives consisted of the following steps:

- Obtain an estimate of the areal extent (i.e., term A in the above equation 5) for each proposed site from Table 3-3.
- Estimate the relative contribution of each RIH to nitrogen and fine-grained sediment export (i.e., term E in equation 5) based on information in the scientific literature, discussions at the regional workshop, and the experience of the scientific staff working on the project. Table 3-11 lists the values of E used.
- Calculate site scores using equations 4-6.
- Normalize scores to a scale of 0-10 using the procedures discussed in the overview of analysis methods (Section D).
- Determine the rank order of alternatives.

Sites projected to have large impacts on material cycles were large upland alternatives including Parkers Island, Point Hope Island, and Cainhoy Road alternatives (Figure 3-10). Upland habitats which are abundant at these sites buffer aquatic habitats from excessive inputs of nutrients, sediments, and other nonpoint

Table 3-11. Values used for relative importance of RIH's to material cycling processes.

Habitat Type	Relative Value Used	Alternate Value Used
Existing Disposal Area	0	1
Upland Habitat	3	
Freshwater Wetlands	3	3
Ponds, Borrow Pits & Impoundments	1	0
Mixed Estuarine Wetlands	3	1
High Elevation Estuarine Wetlands	3	1
Low Elevation Estuarine Wetlands	3	1
Tidal Flats	2	
Small Tidal Creeks	3	1
Large Tidal Creeks	2	
Shallow Estuary	3	
Deep Estuary	2	
Coastal Dunes and Beaches	0	
Shallow Coastal Waters	3	1
Deep Coastal Waters	1	
Live Bottom	1	
Subtidal Coastal Berm	1	

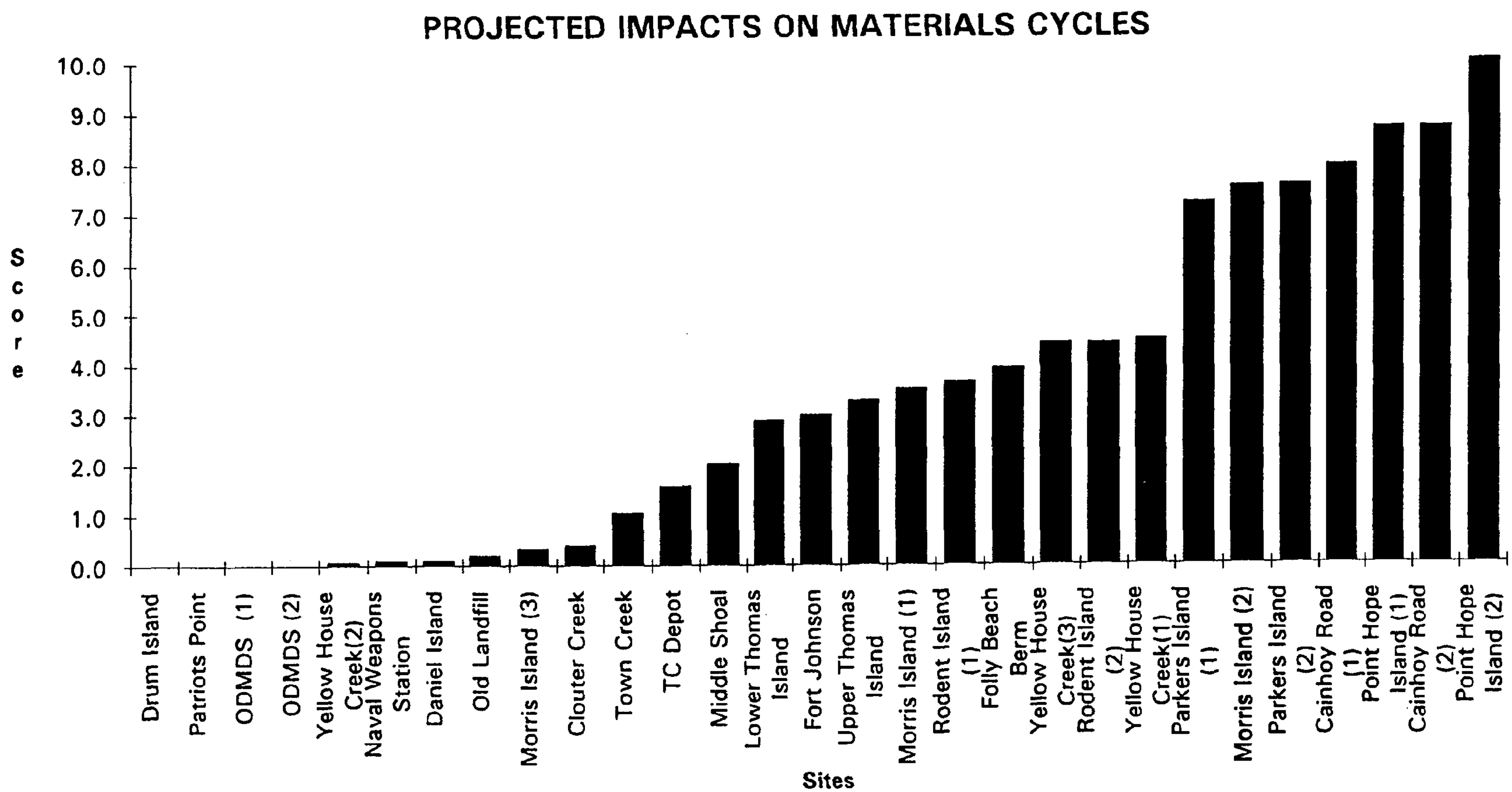


Figure 3-10. Projected impacts on material cycles.

source pollutants (Beaulac and Reckhow 1982). Alternatives projected to result in little or no change in nitrogen and fined-grained sediment export were either existing disposal sites (e.g., Clouter Creek, Daniel Island) or ocean sites where dredged material disposal activities are projected to have little impact upon sediment or nitrogen export (e.g., ODMDS alternatives). Site scores for projected impact on materials cycling was strongly related (r^2=0.72) to the extent (i.e., acres) of upland habitat (Figure 3-11).

Sensitivity analyses were conducted to evaluate the influence that values assigned for the relative contribution of RIHs to sediment and nitrogen export had on normalized site scores for projected impact upon materials cycling. For these analyses, the alternative values for E shown in Table 3-11 were used, and normalized scores and rank order recalculated. Results of these analyses indicated that changes in the values of E had little influence on normalized site scores or site rank order. Correlation coefficients between site scores for the nominal analysis (i.e., standard run) and scores obtained using the alternative values of E shown in Table 3-11 ranged between 0.89 and 1.0.

6. Projected Impacts on Migration and Movement Patterns

Construction and operation of dredged material disposal facilities can block and/or retard seasonal movement and migration patterns of biota if they are poorly sited (e.g., block movement of shrimp into spawning habitats). Blockage of an important migration route for biota was considered a "fatal flaw" for this evaluation. None of the candidate disposal sites blocked an important migration route for RIB. One alternative (i.e., Town Creek), however, potentially restricted movement and migration of biota into a major estuarine system within Charleston Harbor. In addition, several alternatives (e.g., Yellow House Creek alternatives, TC Depot, Rodent Island alternatives) were located along tidal creeks and/or rivers where discharges from a dredged material disposal facility (e.g., contaminant and/or turbidity plumes) may retard movement of organisms into or out of tidal creeks and rivers.

The purpose of this criterion was to identify alternatives that have the potential to adversely influence movement of fish and shellfish to spawning grounds, nursery areas, feeding areas, or overwintering habitats and score them high. Alternatives that were

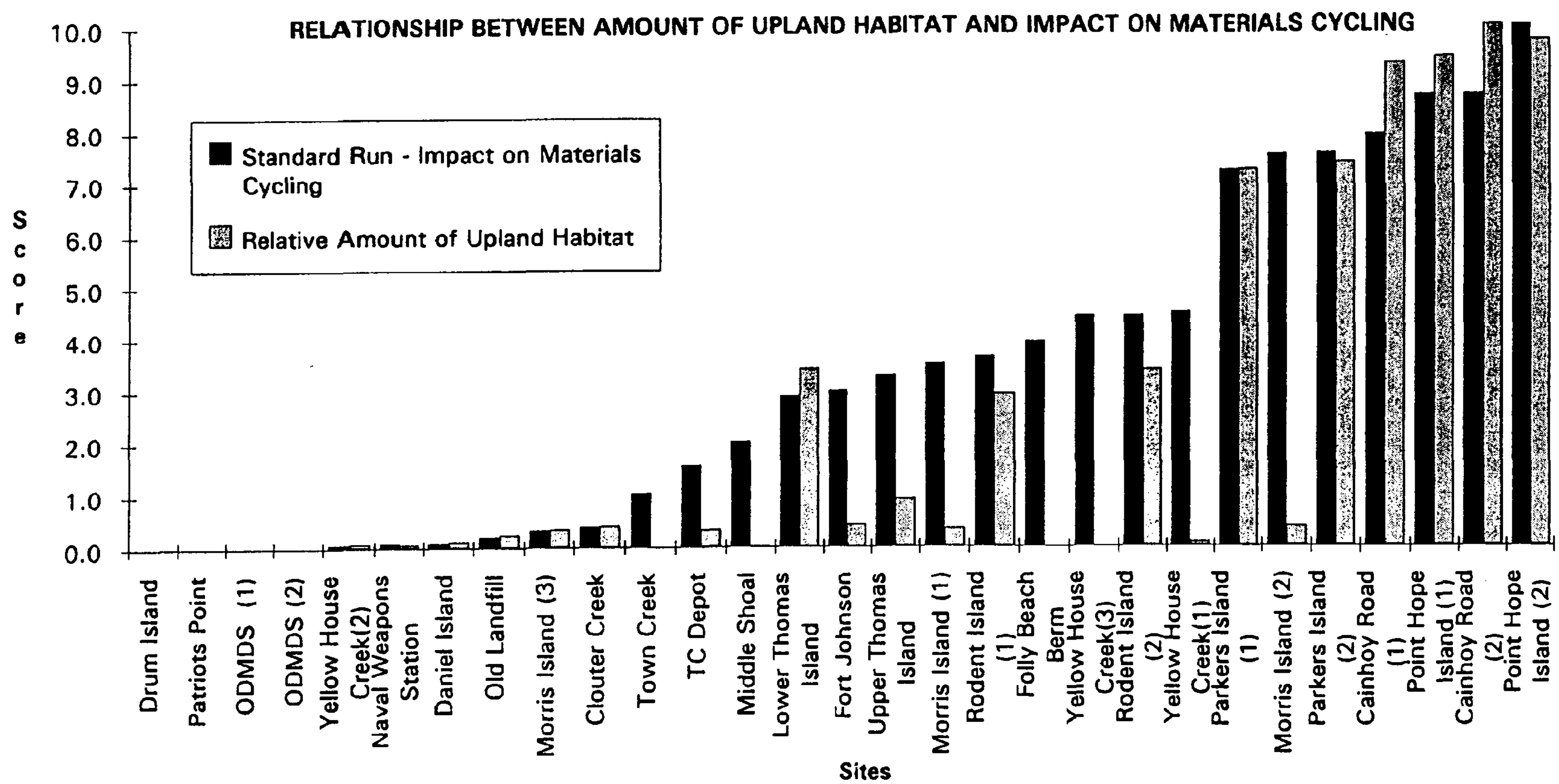


Figure 3-11. Relationship between projected impact on material cycling and amount of upland habitat.

not likely to adversely affect movement patterns were scored low. The indicator for projecting relative impact on migration and movement of RIB used the categorical scoring scheme shown in Table 3-12.

Figure 3-12 provides a summary of the projected impacts on migration and movement patterns. Most alternatives had small impact on migration and movement patterns. The Town Creek alternative was projected to have the largest impacts because it blocked a major migrational route for shrimp and fish into the Cooper River. Development of a dredged material disposal facility at several sites, including Parkers Island - alternative 1, Point Hope Island - alternative 1, Old Landfill, Lower Thomas Island, Rodent Island - alternatives 1 & 2, had the potential to restrict movement of RIB into and out of small creeks and was projected to have moderate impacts on migration and movement patterns.

7. Projected Impacts on Groundwater Resources

The purpose of this criterion was to identify alternatives that were projected to adversely affect groundwater resources and score them high relative to alternatives that were not projected to adversely impact groundwater resources. As previously discussed, the evaluation of impacts on groundwater resources was conducted by WRC. The information presented below summarizes the findings of WRC's assessment presented in a series of letters to the USACOE.

The major regional aquifer likely to be impacted by dredged material disposal in the Charleston Harbor area is the Floridian aquifer. None of the alternatives would adversely affect the Floridian aquifer because the Cooper Formation which overlays it provides a protective barrier from contamination by dredged material disposal activities (Hockensmith 1992). Shallow aquifers occur in sand strata underlying upland sites in the Charleston Harbor region. The greatest threat to groundwater resources associated with construction and operation of dredged material disposal facilities was the contamination of these aquifers (Hockensmith 1992). The mechanisms of contamination for shallow aquifers by dredged material disposal are: (1) leaching of salts from the dredged material into shallow aquifers, (2) contamination of shallow aquifers with saltwater pumped during dredging activities, and (3) lateral seawater intrusion. Lateral seawater intrusion occurs when poorly-sorted, fine-grained, low-permeability dredged material is spread over a site in a manner that diminishes the rate of freshwater recharge from precipitation (Hockensmith 1992).

The evaluation approach used by WRC consisted of the

Table 3-12. Scoring scheme used for assessing impacts on migration and movement patterns.

Impact Category	Score
Projected to alter or restrict ≥50 percent of the available cross-sectional area of a migration or movement pathway for RIB in adjacent habitats - High Impact	10
Projected to alter or restrict movement in ≥10 percent but <50 percent of the available cross-sectional area of a migration and movement pathway for RIB in adjacent habitats - Moderate Impact	7
Projected to alter or restrict movement in <10 percent of the available cross-sectional area (e.g., a discharge plume exists in adjacent habitats but is likely confined to a narrow ribbon along the shoreline) - Low Impact	4
No projected impact on migration or movement patterns for RIB in adjacent habitats - No Measureable Impact	1

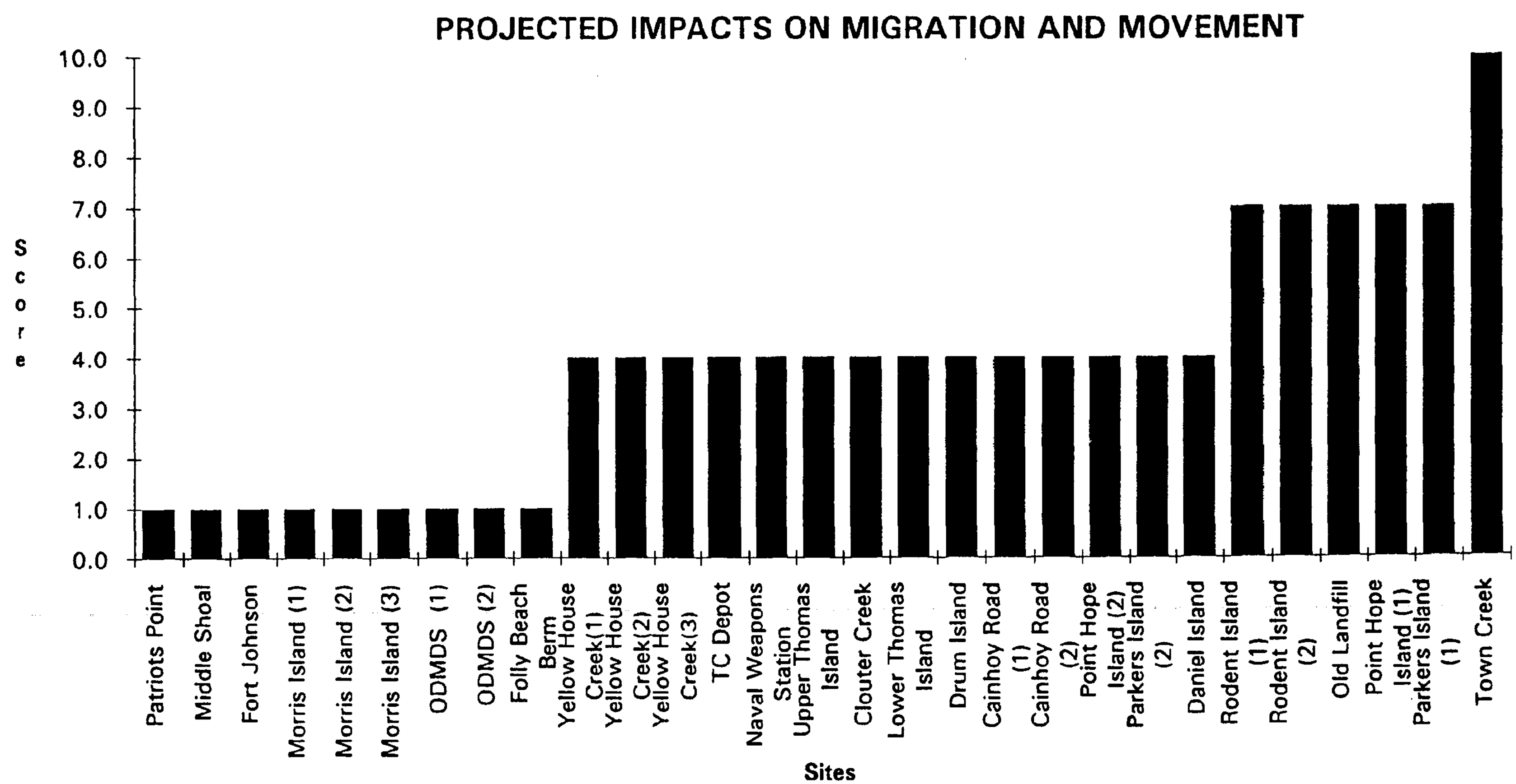


Figure 3-12. **Projected impacts on migration and movement patterns.**

Table 3-13. Scoring scheme used for assessing potential impacts on groundwater resources

Impact Category	Score
Significant Impact	10
Moderate Impact	6
Low Impact	3
No Impact	0

categorical scoring procedure shown in Table 3-13. Alternatives projected to have relatively large impacts on groundwater resources were upland sites that had sandy underlying strata and associated shallow aquifers that have high potential to become contaminated including Rodent Island alternatives, Lower Thomas Island, Cainhoy Road alternatives, Point Hope Island alternatives, Parkers Island alternatives, and Daniel Island (Figure 3-13). Alternatives projected to have no impact on groundwater resources included Middle Shoal, Town Creek, ODMDS alternatives, and the Folly Beach Berm.

8. Projected Impacts on Cultural Resources

The purpose of this criterion was to identify sites that were projected to adversely affect cultural resources and score them high relative to alternatives that were not projected to adversely impact cultural resources. As previously discussed, the evaluation of impacts on cultural resources was conducted by Brockington and Associates, Inc. The assessment conducted by Brockington and Associates, Inc. included: (1) the identification of known cultural resources within or adjacent to candidate sites, (2) an assessment of the effects proposed facilities would likely have on existing cultural resources, (3) an evaluation of the extent to which adverse effects resulting from construction and operation of prospective disposal sites were likely to detract from the significance of culturally important properties, and (4) an evaluation of the potential for unknown cultural resources to occur at each candidate site. The paragraphs that follow represent a summary of the findings presented in the final report prepared by Brockington and Associates, Inc. for the South Carolina Coastal Council and the USACOE (Brockington and Associates, Inc. 1992).

For their evaluation, Brockington and Associates, Inc. determined that the distribution of culturally important resources in the Charleston Harbor area was frequently associated with proximity to tidally affected waterways and the drainage characteristics of soils (Brockington and Associates, Inc. 1992). Associations between prehistoric cultural resources and waterways were related to the need for prehistoric humans to find food (e.g., fish and shellfish). The association of historic cultural resources with marshes and tidal streams was related to the historic use of waterways as transportation routes (South and Hartley 1985). Drainage characteristics of soils were related to the suitability of sites for human habitation. Dry, well-drained soils were more likely to have been inhabited and contain cultural resources than poorly drained soils (e.g., Brooks and Scurry 1979). Brockington and Associates, Inc. (1992) also determined the proximity of known culturally important resources to prospective

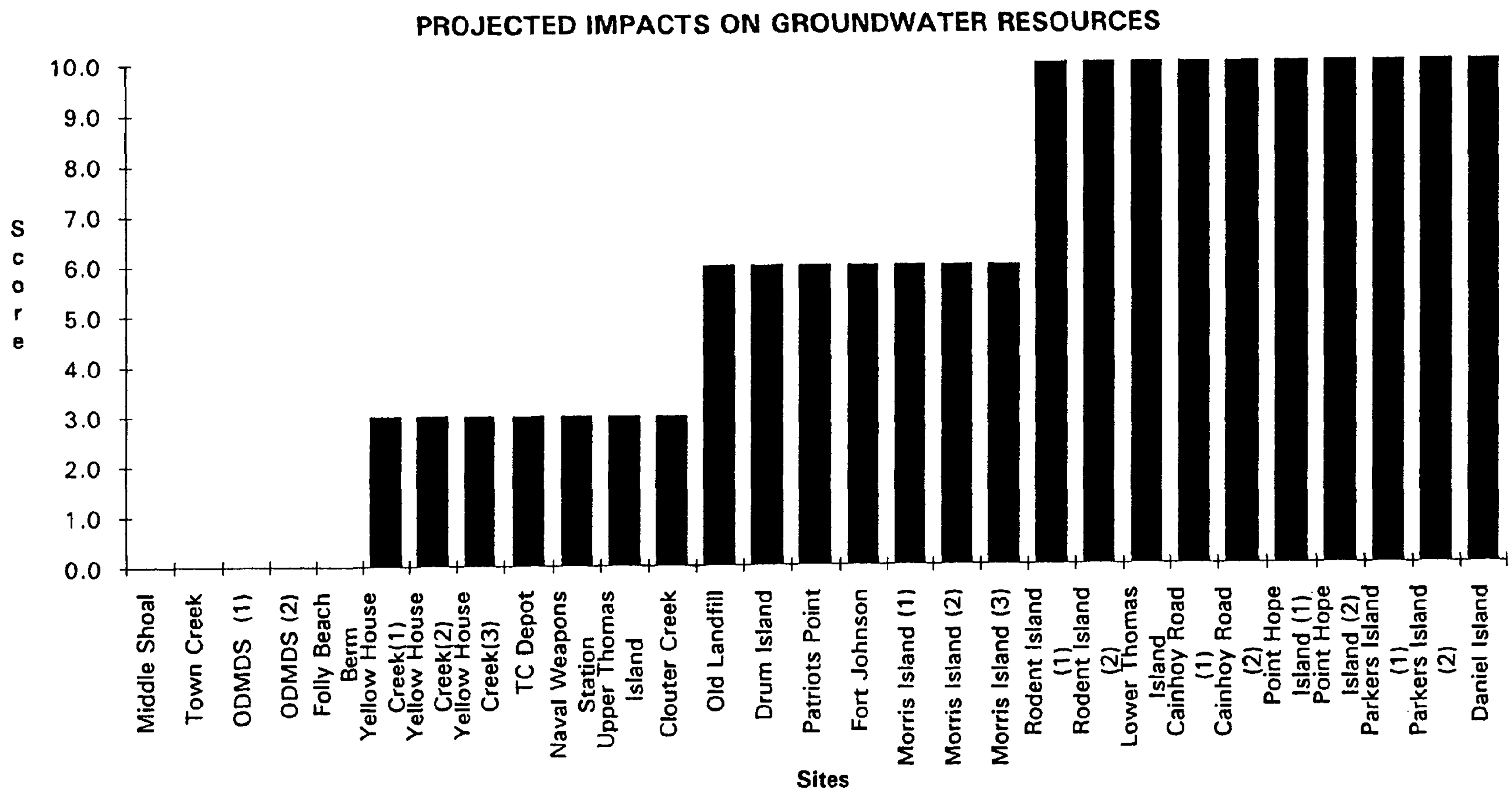


Figure 3-13. Projected impacts on groundwater resources.

sites from the recent archaeological literature. This information was summarized on maps.

Brockington and Associates, Inc (1992) used proximity to tidally affected waterways and drainage characteristics of soils to estimate the potential for unknown culturally important resources to occur at alternative sites. This assessment concluded that the Upper Thomas Island site and Morris Island alternatives 1 and 2 had high potential to contain unknown cultural resources. Lower Thomas Island, Rodent Island alternatives, Middle Shoal, Cainhoy Road alternatives, Point Hope Island alternatives, and Town Creek had moderate potential for containing unknown cultural resources. Yellow House Creek alternatives 1 and 2, TC Depot, Parkers Island, Old Landfill, Fort Johnson, ODMDS alternatives, and the Folly Beach Berm had low potential for containing unknown cultural resources. Existing dredged material disposal sites including Yellow House Creek alternative 3, Naval Weapons Station, Clouter Creek, Drum Island, Patriots Point, Morris Island alternative 3, and Daniel Island had no potential for containing unknown cultural resources.

Once the potential for each site to contain unknown cultural resources had been determined and the location of known cultural resources had been mapped, an assessment of the effects of construction and operation of dredged material disposal facility for each alternative was completed. This assessment included identification of direct effects that were likely to occur as well as the visual effects of construction and operation of dredged material disposal facilities on culturally important properties. Three categories of cultural resources were determined to be at risk. These were: (1) known properties on the National Register of Historic Places (NRHP), (2) properties that were eligible or potentially eligible for inclusion on the NRHP, and (3) adverse effects to unknown resources that may exist at each site. The categorical scoring scheme shown in Table 3-14 was used by Brockington and Associates, Inc. (1992) to quantify the projected effects for each category of cultural resource at risk. Scores were then summed across the three categories to estimate overall impact to cultural resources. The maximum possible score was 15 (i.e., extreme apparent adverse effects to all three categories of cultural resources). The minimum score was zero (i.e., no effect on cultural resources).

Table 3-15 summarizes the findings of the Brockington and Associates, Inc. assessment. Brockington and Associates, Inc. scores were normalized to a scale of 0-10 using the normalization procedure defined in the overview of analysis methods (Section D). This normalization was necessary to ensure that projected impacts on cultural resources were equally weighted with the scoring system

Table 3-14. Categorical scoring scheme used for assessing impacts on cultural resources

Impact Category	Score
Extreme adverse effects	5
Moderate adverse effects	3
Minimal adverse effects	1
No projected Impact	0

Table 3-15. Summary of findings for projected relative impacts on cultural resources.

Alternate Sites	Brockington and Associates Score	Normalized Score Calculated by MRD
Yellow House Creek - Alternative 1	1	0.7
Yellow House Creek - Alternative 2	1	0.7
Yellow House Creek - Alternative 3	1	0.7
Rodent Island - Alternative 1	3	2
Rodent Island - Alternative 2	3	2
T C Depot	1	0.7
Naval Weapons Station	0	0
Upper Thomas Island	5	3.3
Clouter Creek	0	0
Lower Thomas Island	5	3.3
Old Landfill	1	0.7
Drum Island	0	0
Patriots Point	0	0
Middle Shoal	8	5.3
Fort Johnson	6	4
Morris Island - Alternative 1	15	10
Morris Island - Alternative 2	15	10
Morris Island - Alternative 3	10	6.7
Cainhoy Road - Alternative 1	3	2
Cainhoy Road - Alternative 2	3	2
Point Hope Island - Alternative 1	3	2
Point Hope Island - Alternative 2	3	2
Parkers Island - Alternative 1	6	4
Parkers Island - Alternative 2	6	4
Town Creek	3	2
Daniel Island	0	0
ODMDS - Alternative 1	0	0
ODMDS - Alternative 2	0	0
Folly Beach Berm	0	0

used for other environmental concerns. Normalized scores summarizing the findings of the Brockington and Associates, Inc. evaluation are summarized in Figure 3-14.

Sites with low potential for adversely affecting cultural resources were mainly existing or historically used dredged material disposal areas including the Yellow House Creek alternative, Naval Weapons Station, Clouter Creek, Drum Island, Patriots Point, Daniel Island, ODMDS alternatives, the Folly Beach Berm, TC Depot, and Old Landfill. These sites generally require small amounts of new construction and are not located in areas that represent historically valuable landscapes. Although some underwater resources may be present at the ocean disposal sites, adverse effects to these underwater resources would likely be negligible. Rodent Island alternatives, Cainhoy Road alternatives, Point Hope Island alternatives, and Town Creek have moderate potential for containing unknown cultural resources but do not impact any culturally important properties. The Upper and Lower Thomas Island sites have high potential for containing unknown cultural resources and are projected to experience modest adverse effects. The Fort Johnson, Parkers Island alternatives, and Middle Shoal sites have high potential for adversely affecting cultural resources. The Fort Johnson site would be visible from Fort Sumter, and the Parkers Island site contains 18 known archaeological sites; 15 of which are eligible or potentially eligible for inclusion on the NRHP. Construction and operation of a dredged material disposal facility at Middle Shoal would not only potentially degrade scenic views of Castle Pinckney (an NRHP listed property) and Charleston Harbor, this site has the potential to contain unknown submerged cultural resources (e.g., wrecked ships). Morris Island alternatives 1 and 2 represent the greatest threat to cultural resources. These alternatives are located near a NRHP property (i.e., the Morris Island Lighthouse), may incorporate resources eligible for inclusion on the NRHP (i.e., two civil war wrecks), and also may adversely affect unknown cultural resources related to Civil War activities on Morris Island. The existing disposal site at Morris Island (i.e., Morris Island - Alternative 3) had the next greatest potential for adversely affecting cultural resources as it would adversely affect scenic vistas of the Morris Island Lighthouse as well as the two Civil War wrecks.

9. Projected Impacts on Human Uses

The purpose of this criterion was to identify alternatives that were projected to have large adverse effects on human uses (i.e., fishing, hunting, shellfish harvesting, swimming, boating, aesthetics) and score them high. Alternatives that were projected to have small impacts on human uses were scored low. The indicator

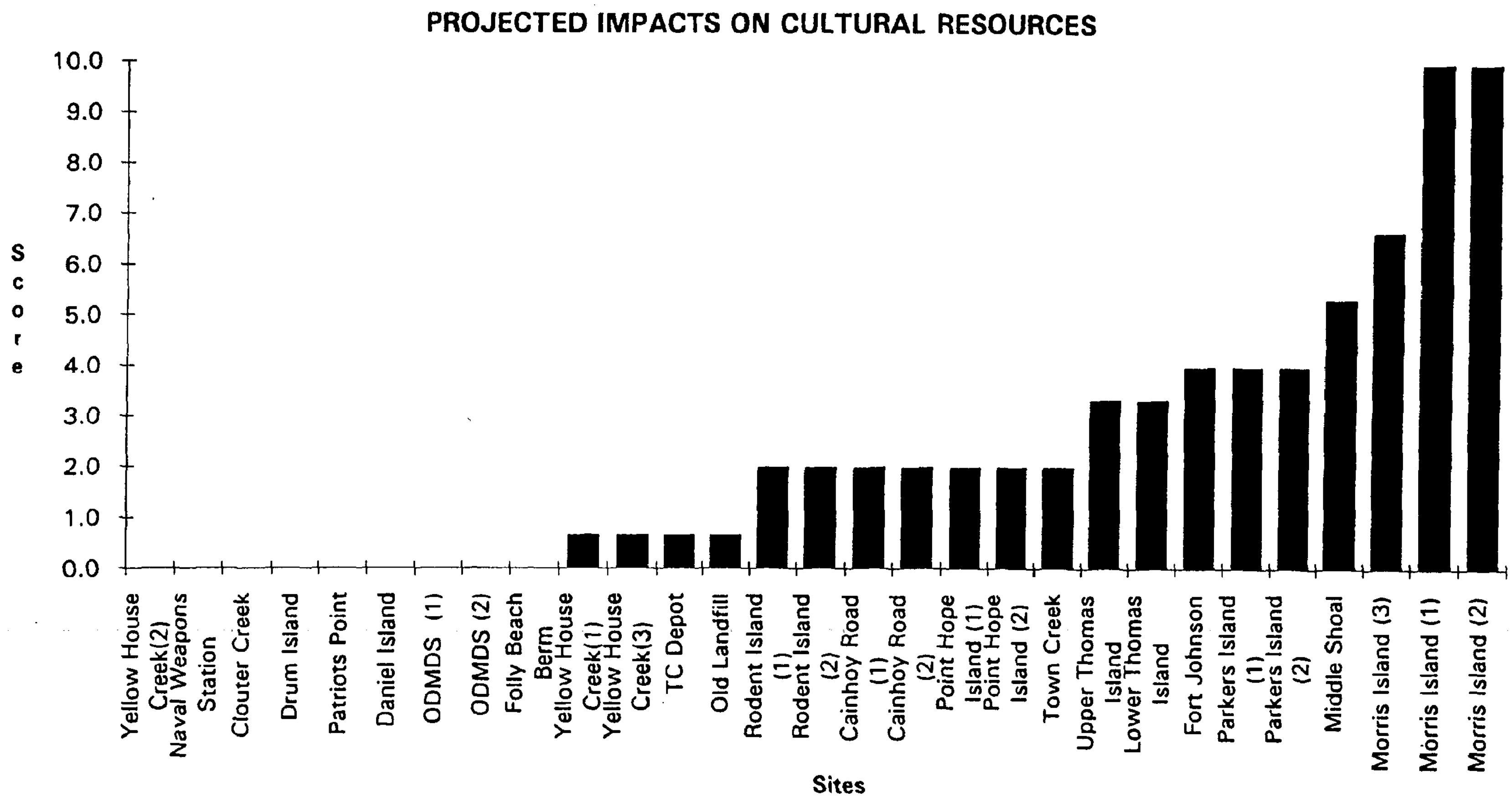


Figure 3-14. Projected impacts on cultural resources.

used to project adverse impacts on human uses was:

$$\text{Projected Human Use Impacts} = B - D \tag{7}$$

where:

B = Measure of the relative magnitude of human use before construction and operation of a dredged material disposal facility.

D = Measure of the relative magnitude of human uses during and after operation of a dredged material disposal facility commences.

$$B = \sum_{i=1}^{16} (A_i * V_i) \tag{8}$$

where:

A_i = Area of the ith Representative Important Habitat at each disposal site.

V_i = Categorical variable ranging from 0 (low value) to 3 (high value) representing the relative value of the ith habitat for human uses identified in Table 3-13.

i = 1-16 representing the RIHs included in the assessment.

$$D_j = \sum_{j=1}^{29} (A_j' * E_j') \tag{9}$$

A_j' = Area of jth proposed dredged material disposal site.

E' = Constant representing the relative value of dredged material disposal sites to humans.

j = 1-29 representing the alternative configurations evaluated.

The impacts of construction and operation of a dredged material disposal site on human uses are a function of: (1) the habitat type present at each site before construction, (2) the relative value of each habitat for supporting human uses, and (3) the size of the proposed dredged material disposal facility. All of these factors were incorporated into equations 7-9.

The procedure used to calculate site scores for projecting impacts on human uses consisted of the following steps:

- Obtain an estimate of the areal extent of each RIH for each alternative (i.e., term A in equation 8) from Table 3-3.
- Estimate the relative value of each RIH for human uses (i.e., term V in equation 8). Table 3-16 lists the values of V used. The procedure for defining the relative value of RIHs consisted of the following steps: (1) develop a list of potential human uses (Table 3-17), (2) determine the number of uses that was associated with each habitat type, and (3) assign a categorical value ranging from 0-3 to each habitat based on the number of human uses that existed at each site.
- Estimate of the areal extent of the proposed dredged material disposal facility (term A′ in equation 9) from Table 3-3.
- Calculate site scores using equations 7-9.
- Normalize scores to a scale of 0-10 using the procedures discussed in the overview of analysis methods (Section D).
- Determine the rank order of alternatives.

Alternatives where development of a dredged material disposal facility was projected to have large impacts on human uses were large sites composed of diverse habitats that supported multiple human uses such as ODMDS alternative 1, Point Hope Island alternatives, Parkers Island alternatives, Cainhoy Road alternatives, and Yellow House Creek alternatives 1 & 3 (Figure 3-15). Sites where construction and operation of dredged material disposal facilities were projected to have small impacts on human uses were small sites or existing disposal sites (e.g., Patriots Point, Drum Island, Yellow House Creek alternative 2, Naval Weapons Station, and Old Landfill).

Sensitivity analyses were conducted to evaluate the influence that changes in the relative value of RIHs for human uses (term V in equation 8) on normalized scores and rank order. For these analyses, the alternative use values in Table 3-16 were used and scores and ranks recalculated. These analyses indicated that changing any one or several of the human use values resulted in only small changes in the normalized site scores and site rank

Table 3-16. Relative value of RIHs for projecting impacts on human uses.		
Habitat Type	Human Use Index	Alternate Human Use Index
Existing Disposal Area	1	
Upland Habitat	2	1 & 3
Freshwater Wetlands	3	2
Ponds, Borrow Pits & Impoundments	2	1
Mixed Estuarine Wetlands	3	2
High Elevation Estuarine Wetlands	1	1
Low Elevation Estuarine Wetlands	2	2
Tidal Flats	2	
Small Tidal Creeks	2	
Large Tidal Creeks	3	
Shallow Estuary	2	
Deep Estuary	3	
Coastal Dunes and Beaches	2	
Shallow Coastal Waters	1	
Deep Coastal Waters	1	
Live Bottom	3	

Table 3-17. **List of human uses considered.**

Dredged material disposal
Fishing and/or hunting
Swimming, boating, diving and/or other aesthetic uses (e.g., bird-watching, natural vistas, hiking)

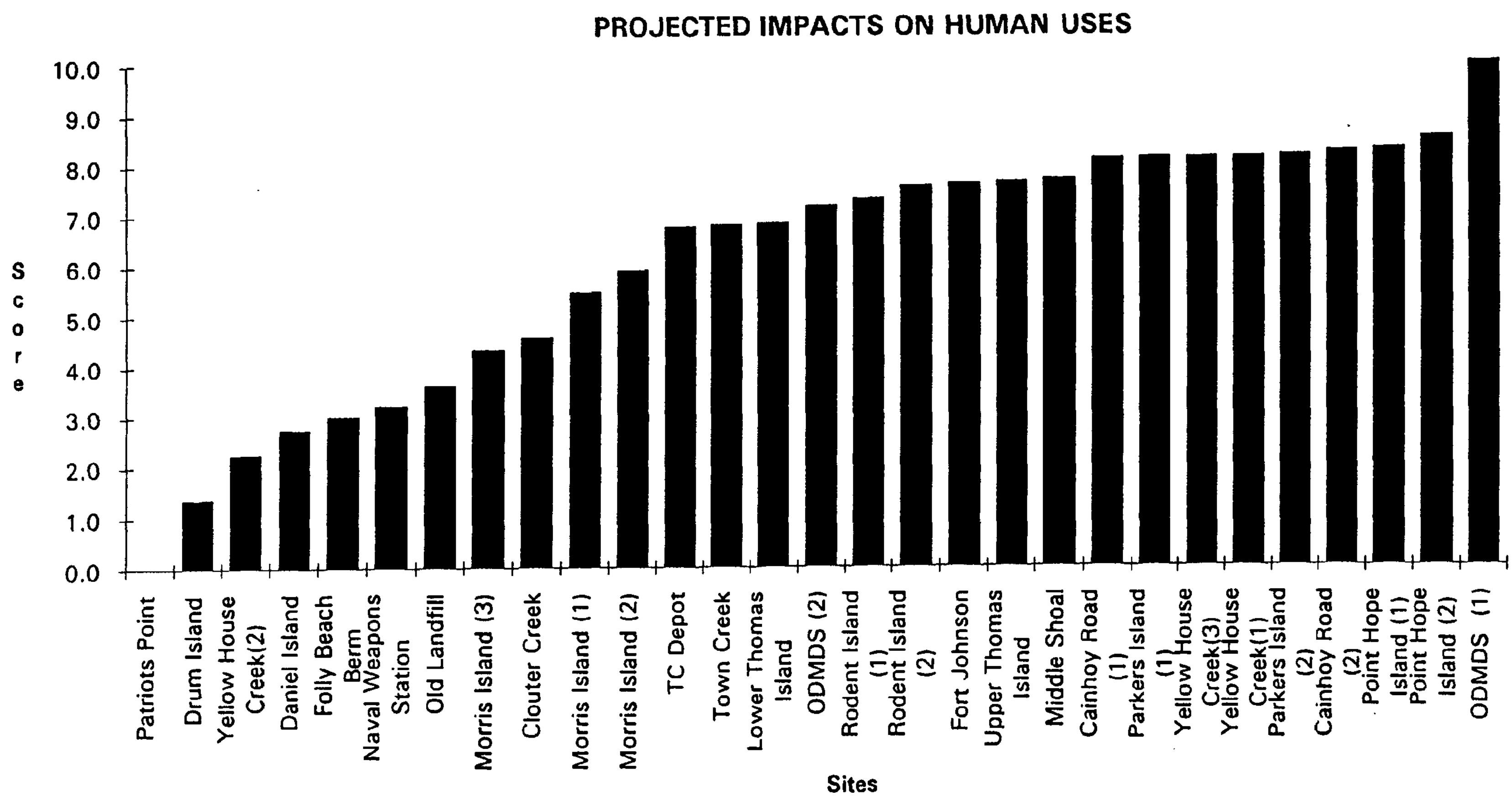


Figure 3-15. Projected impacts on human uses.

order. Normalized scores for impacts on human uses were not strongly associated with site size or disposal capacity and were related to the reduction in the number of human uses that would not occur after development or the size of the area over which uses would be eliminated. Based on results of the sensitivity analyses, it was concluded that the indicator for projecting impacts on human uses was adequately developed and not likely to be adversely influenced by errors that may be associated with assignment of human use values.

10. Cumulative Environmental Impact Assessment

Figure 3-16 and Table 3-18 present an assessment of projected cumulative environmental impacts for the 20 sites and 29 alternatives. Projected cumulative environmental impact was calculated by summing site scores for all environmental concerns evaluated (i.e., summing down columns in Table 3-18). Alternatives are rank ordered in Figure 3-16 from the alternative projected to have the smallest cumulative environmental impact (far left) to the alternative projected to have the largest cumulative environmental impact. Associations between projected cumulative environmental impacts and size and capacity are presented in Figure 3-17.

All environmental concerns were equally weighted in the analysis conducted for Figure 3-16. The analytical approach was developed, however, in a manner that allowed each environmental concern to be weighted to any degree that could be justified. For example, agencies responsible for the regulation of dredged material disposal sites have traditionally emphasized the loss of critical habitats and adverse effects on water quality when siting dredged material disposal facilities. During this assessment, the weighting schemes shown in Table 3-19 were evaluated to determine the degree to which alternative weighting schemes affected results and conclusions. Figures 3-18 through 3-20 present representative results obtained from applying alternative weighting schemes. Weighting factors greater than five were not evaluated because they were considered to be unrealistically high.

Weighting projected impacts on water quality five times as important as other environmental concerns altered the rank order and distribution of alternatives to a greater degree than any of the other weighting schemes evaluated (Figure 3-19). None of the other weighting schemes evaluated substantially altered the rank order or distributional pattern of alternatives (Figures 3-18 and 3-20). Based on these analyses, it was concluded that the analysis approach was robust to reasonable alternative weighting schemes and application of alternative schemes would not substantially alter results. In addition, discussions at the regional workshop

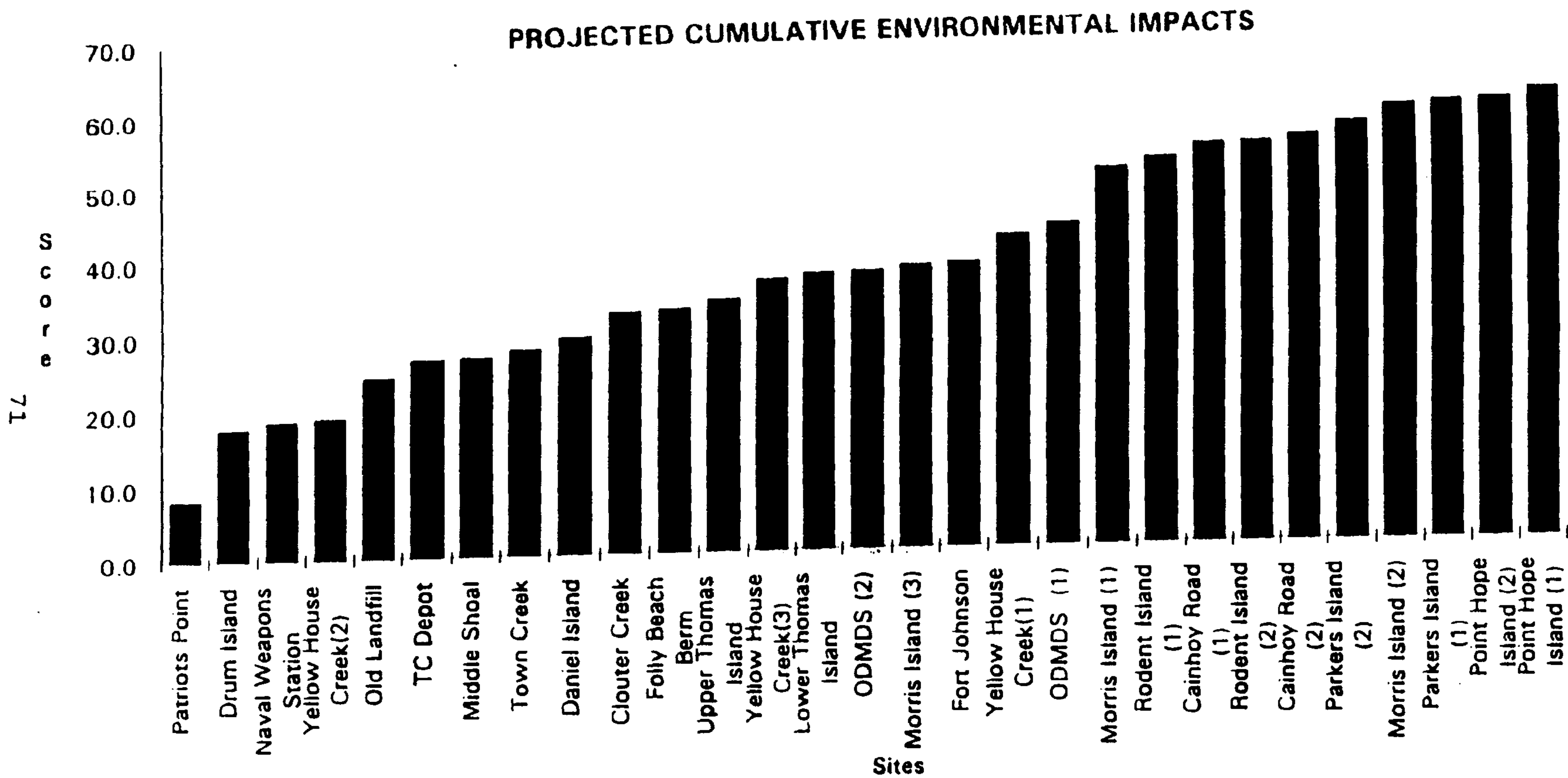
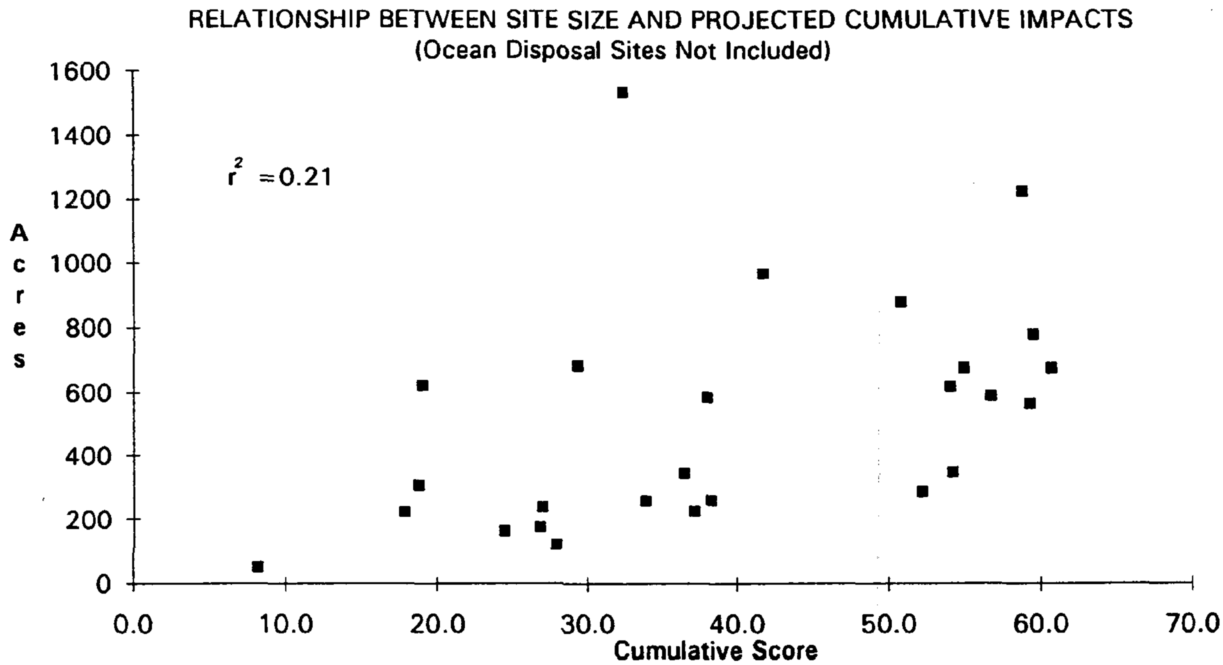


Figure 3-16. Projected cumulative environmental impacts.



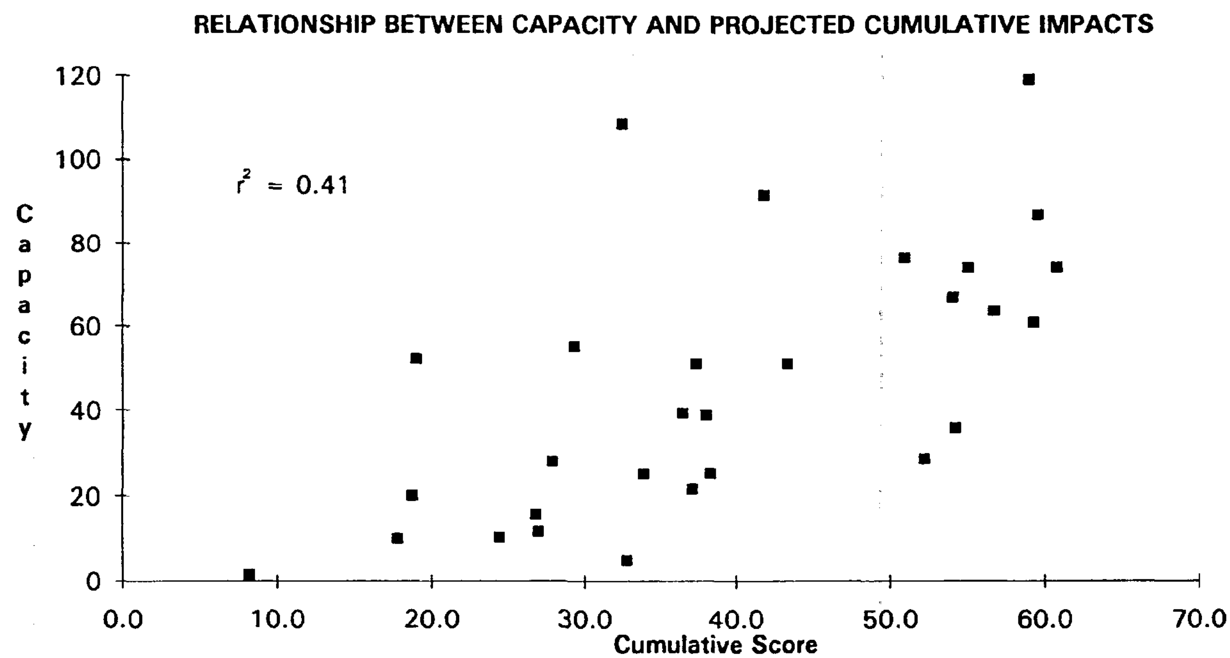


Figure 3-17. **Relationship between projected cumulative environmental impacts and size (A) and capacity (B).**

Table 3-18A. Overview of analysis results.

Evaluation Criteria	Alternative Sites															Weighing Factor
	Yellow House Creek Alt 1	Yellow House Creek Alt 2	Yellow House Creek Alt 3	Rodent Island-Alt 1	Rodent Island-Alt 2	TC Depot*	Naval Weapns Center	Upper Thomas Island	Clouter Creek*	Lower Thomas Island	Old Landfill *	Drum Island	Patriots Point*	Middle Shoal	Fort Johnson *	
Existing Environmental Quality	1.0	1.0	1.0	8.8	8.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	5.0	1
Discharge Impacts on Water Quality	8.1	3.9	4.0	3.1	3.7	1.3	1.7	2.1	10.0	1.6	1.0	0.7	0.0	0.4	2.0	1
Loss of Critical Habitat	7.4	1.9	7.3	6.6	6.8	6.1	3.0	6.9	4.0	5.8	3.1	1.7	0.0	6.5	6.9	1
Impacts on Adjacent Habitat	5.1	2.9	3.9	3.8	4.0	2.3	2.8	2.7	5.5	1.6	1.8	3.1	0.2	3.0	2.8	1
Impacts on Material Cycles	4.5	0.1	4.4	3.6	4.4	1.6	0.1	3.3	0.4	2.9	0.2	0	0.0	2.0	3.0	1
Impacts on Migration and Movement	4.0	4.0	4.0	7.0	7.0	4.0	4.0	4.0	4.0	4.0	7.0	4.0	1.0	1.0	1.0	1
Impacts on Human Uses	8.2	2.2	8.1	7.3	7.6	6.8	3.2	7.7	4.6	6.9	3.6	1.4	0.0	7.7	7.6	1
Impacts on Groundwater Quality	3.0	3.0	3.0	10.0	10.0	3.0	3.0	3.0	3.0	10.0	6.0	6.0	6.0	0	6.0	1
Impacts on Cultured Resources	0.7	0	0.7	2.0	2.0	0.7	0	3.3	0	3.3	0.7	0	0	5.3	4.0	1
Cumulative Environmental Impacts (Σ)	41.8	19.1	36.5	52.2	54.2	26.8	18.8	33.9	32.5	37.2	24.4	17.8	8.2	27.0	38.3	
Capacity (10^6cu yd)	91.6	55.2	39.4	28.6	35.6	15.6	20.0	25.2	108.8	21.6	10.4	10.1	21.6	11.8	25.4	
Capacity Adjusted Score (score/10^6cu yd)	0.46	0.37	0.93	1.83	1.52	1.72	0.94	1.35	0.30	1.72	2.35	1.77	5.12	2.28	1.51	
Normalized Cumulative Impacts	6.4	2.1	5.4	8.4	8.8	3.5	2.0	4.9	4.6	5.5	3.1	1.8	0	3.6	5.7	
Normalized Capacity Adjusted Score	0.3	0.1	1.0	2.4	2.0	2.3	1.0	1.7	0	2.3	3.3	2.3	7.7	3.2	1.9	
Sum Cumulative Impact and Capacity Adjusted Score	6.6	2.2	6.4	10.8	10.7	5.8	3.0	6.6	4.6	7.8	6.3	4.2	7.7	6.7	7.7	
Rank Order	12	1	10	27	25	7	2	11	5	18	9	3	17	13	16	

* = Existing disposal sites

Table 3-18B. Overview of analysis results.

Evaluation Criteria	Morris Island-Alt 1*	Morris Island-Alt 2	Morris Island-Alt 3	Cainhoy Road-Alt 1	Cainhoy Road-Alt 2	Point Hope Island-Alt 1	Point Hope Island-Alt 2	Parkers Island-Alt 1	Parkers Island-Alt 2	Town Creek	Daniel Island	ODMD S-Alt 1*	ODMD S-Alt 2*	Off-shore Berm	Weighing Factor
Existing Environmental Quality	10.0	10.0	10.0	8.8	8.8	8.8	8.8	8.8	8.8	1.0	1.0	10.0	10.0	10.0	1
Discharge Impacts on Water Quality	5.2	7.7	3.1	3.3	3.6	5.0	5.3	3.8	3.8	1.2	4.8	2.3	2.2	1.0	1
Loss of Critical Habitat	6.3	7.0	3.8	6.9	7.1	7.2	7.4	7.1	7.1	5.8	2.3	10.0	8.6	6.5	1
Impacts on Adjacent Habitat	3.4	3.9	2.7	3.1	2.8	3.9	3.5	3.4	3.3	0.0	4.4	10.0	8.3	7.3	1
Impacts on Material Cycles	3.5	7.5	0.3	7.9	8.7	8.7	10.0	7.2	7.5	1.1	0.1	0.0	0.0	3.9	1
Impacts on Migration and Movement	1.0	1.0	1.0	4.0	4.0	7.0	4.0	7.0	4.0	10.0	4.0	1.0	1.0	1.0	1
Impacts on Human Uses	5.5	5.9	4.3	8.1	8.2	8.3	8.5	8.1	8.2	6.8	2.7	10.0	7.2	3.0	1
Impacts on Groundwater Quality	6.0	6.0	6.0	10.0	10.0	10.0	10.0	10.0	10.0	0	10.0	0	0	0	1
Impacts on Cultured Resources	10.0	10.0	6.7	2.0	2.0	2.0	2.0	4.0	4.0	2.0	0	0	0	0	1
Cumulative Environmental Impacts (Σ)	50.9	59.0	38.0	54.1	55.0	60.8	59.6	59.3	56.8	27.9	29.4	43.3	37.4	32.8	
Capacity (10^6cu yd)	76.4	117.0	39.0	67.0	74.0	102.2	86.8	60.8	63.6	28.0	55.2	51.0	51.0	10.0	
Capacity Adjusted Score (score/10^6cu yd)	0.67	0.50	0.48	0.81	0.74	0.82	0.69	0.98	0.89	1.00	0.53	0.85	0.73	6.56	
Normalized Cumulative Impacts	8.1	9.7	5.7	8.7	8.9	10.0	9.8	9.7	9.2	3.7	4.0	6.7	5.6	4.7	
Normalized Capacity Adjusted Score	0.6	0.3	1.1	0.8	0.7	0.8	0.6	1.1	0.9	1.1	0.4	0.9	0.7	10.0	
Sum Cumulative Impact and Capacity Adjusted Score	8.7	10.0	6.6	9.5	9.6	10.8	10.4	10.8	10.2	4.9	4.4	7.6	6.2	14.7	
Rank Order	19	22	14	20	21	28	24	26	23	6	4	15	8	29	

* = Existing disposal sites

Table 3-19. List of alternative weighting schemes of environmental concerns evaluated.

Environmental Concern	Weighting Schemes Evaluated										
Impact on Existing Environmental Quality	1	1	1	1	1	1	1	1	1	1	1
Impact on Water Quality	1	2	5	1	1	2	1	1	1	2	5
Critical Habitat Losses	1	1	1	2	5	2	1	1	1	2	5
Impact on Adjacent Environments	1	1	1	1	1	1	2	1	1	1	1
Impact on Material Cycles	1	1	1	1	1	1	1	2	5	2	5
Impact on Migration and Movement	1	1	1	1	1	1	1	1	1	1	1
Impact on Groundwater Resources	1	1	1	1	1	1	1	1	1	1	1
Impact on Cultural Resources	1	1	1	1	1	1	1	1	1	1	1
Impact on Human Uses	1	1	1	1	1	1	1	1	1	1	1

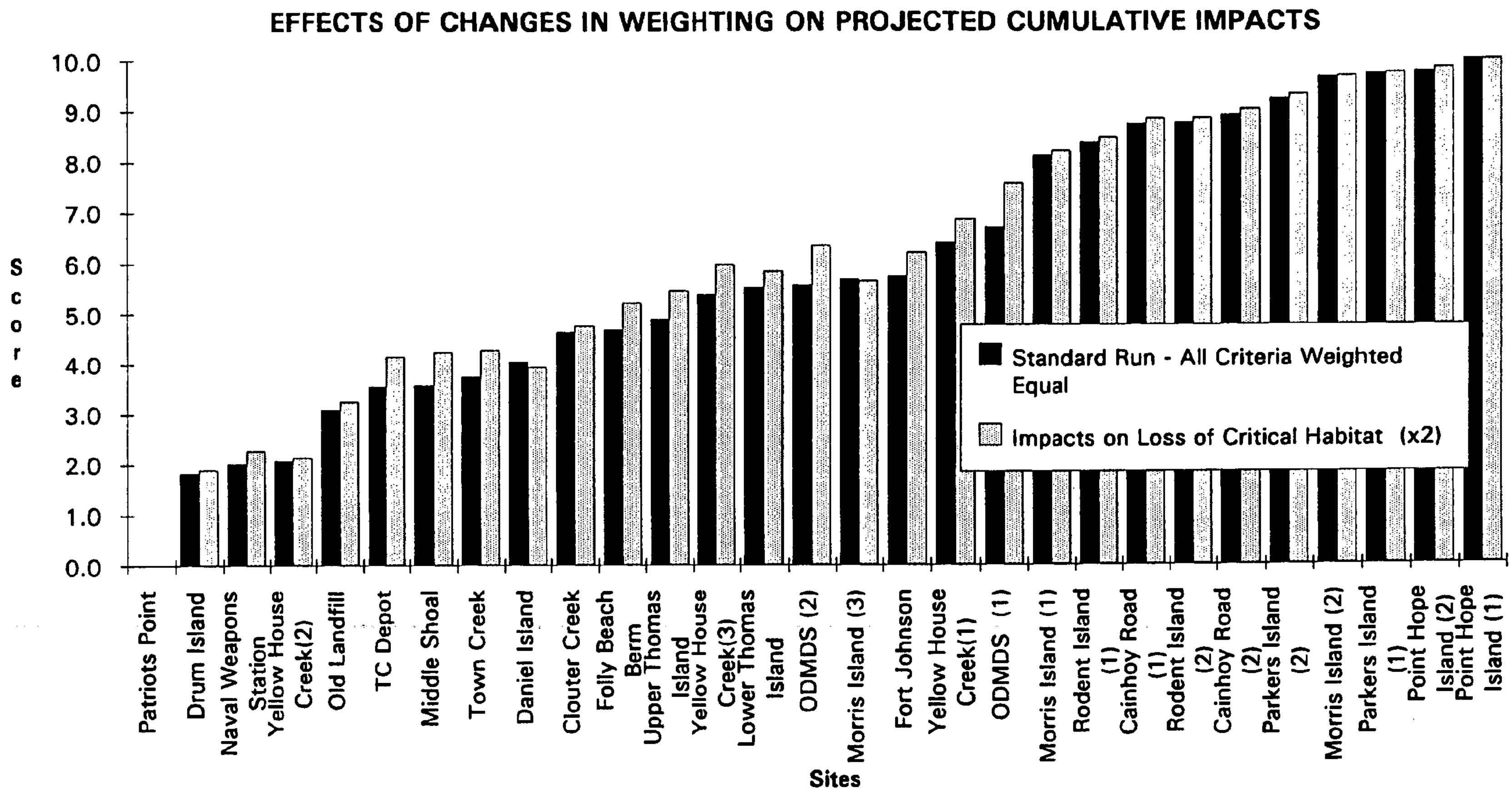


Figure 3-18. **Summary of the effects of weighting projected impacts from critical habitat losses twice as important as other environmental concerns.**

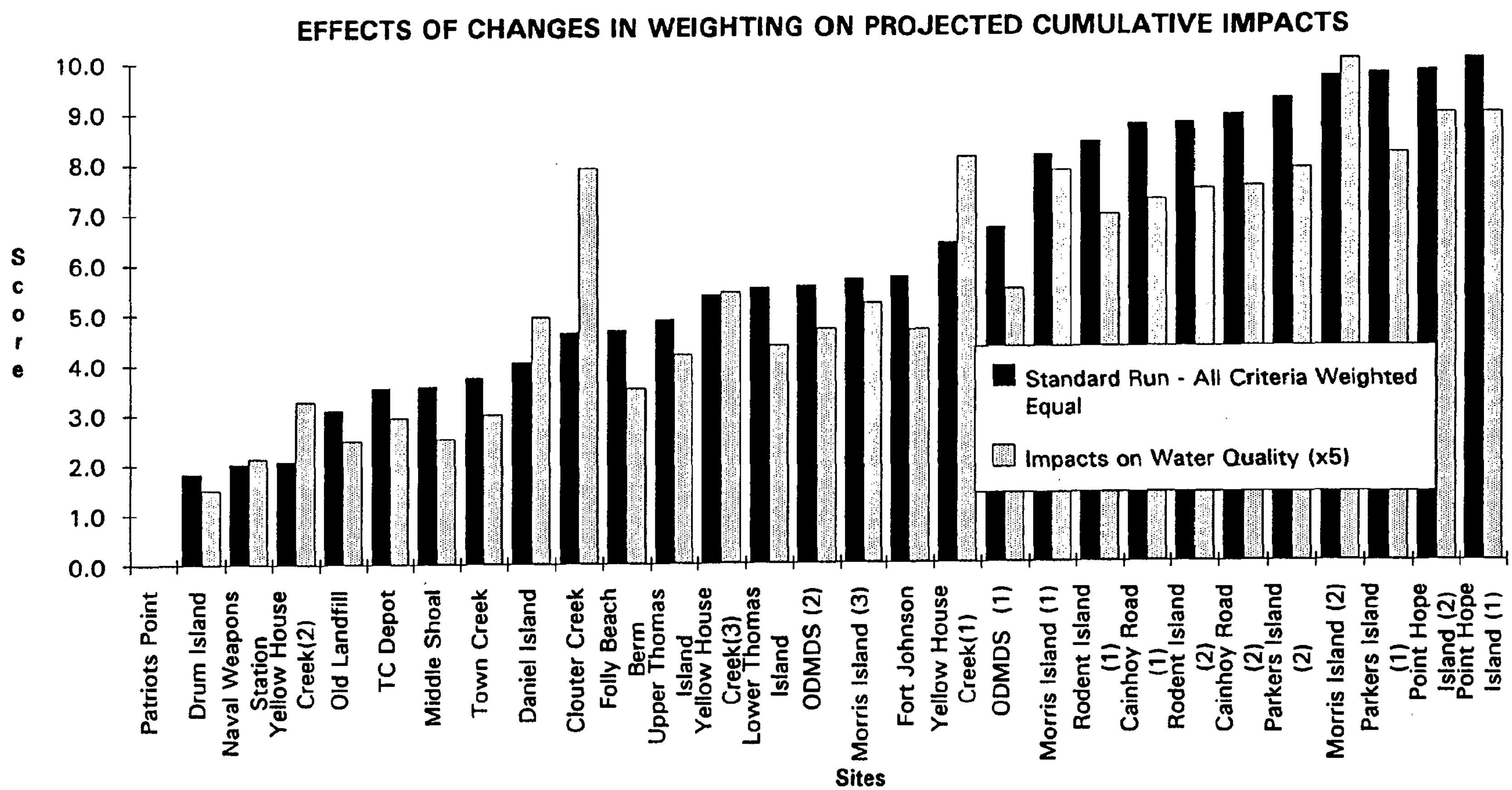


Figure 3-19. **Summary of the effects of weighting projected water quality impacts five times as important as other environmental concerns.**

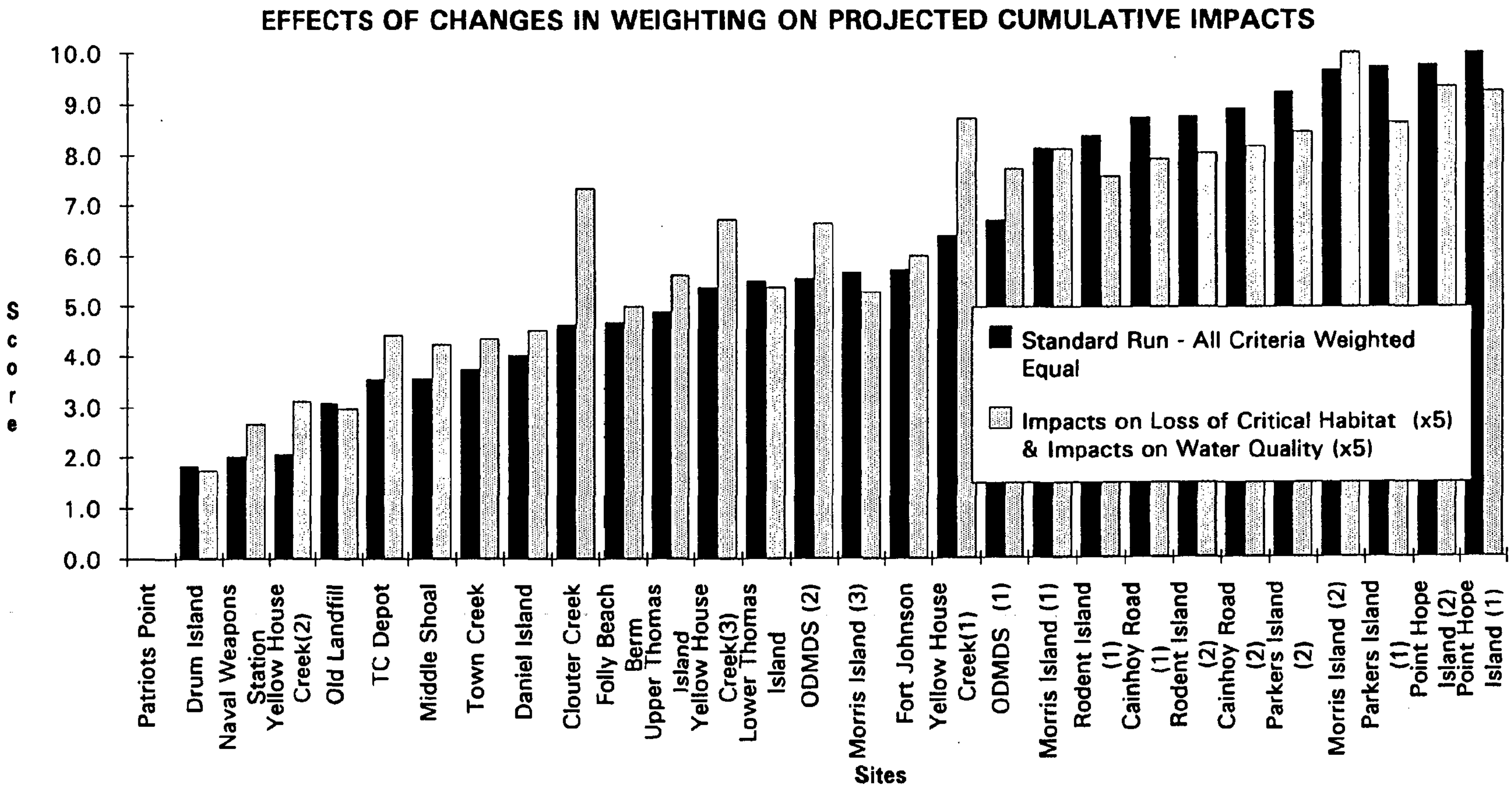


Figure 3-20. **Summary of the effects of weighting projected critical habitat losses and water quality impacts five times as important as other environmental concerns.**

suggested there was little justification for considering any of the environmental concerns to be substantially more important than the others. Analysis conducted for this assessment therefore, weighted all environmental concerns equally.

The degree to which scores for any specific concern (e.g., impacts on water quality) could be used to represent overall cumulative environmental impact was evaluated using a correlation matrix. The concern that best represented overall cumulative environmental impacts was projected impacts on critical habitat losses (Figure 3-21). Relationships between scores for other environmental concerns and projected cumulative impact were substantially weaker ($0.2 \geq r^2 \leq 0.4$). Although critical habitat losses were a reasonable indicator of cumulative impact, it contained only a small portion of the information in the cumulative environmental assessment score ($r^2=0.51$).

Figure 3-22 presents a summary of projected cumulative environmental impacts per cubic yard disposal capacity. This analysis endpoint is analogous to the engineering/economic assessment endpoint of dollar cost per cubic yard disposal capacity and should be considered when evaluating the threat of alternatives to environmental resources. This assessment endpoint is, however, biased against sites with small capacity (e.g., Patriots Point, Drum Island) even if they have relatively small cumulative environmental impact.

Alternatives that have both small cumulative environmental impact (far left of Figure 3-16) and have small environmental costs per cubic yard disposal capacity (far left of Figure 3-22) are the ones that represent the least long-term threat to environmental resources. These sites were identified by combining the results of the cumulative environmental impact assessment with those of the analysis defining the environmental costs per cubic yard disposal capacity. Results of this analysis are presented in Figure 3-23. The information presented in Figure 3-23 equally weights cumulative environmental impacts and environmental costs per cubic yard disposal capacity and is presented on the final two lines of Table 3-18. This final analysis suggests that the use of existing permitted dredged material disposal sites in Charleston Harbor including Yellow House Creek alternative 2, Naval Weapons Station, Drum Island, Clouter Creek, and ODMDS alternative 2 represent the least long-term threat to environmental resources. Several historically used sites also have acceptable impacts on environmental resources including TC Depot and Old Landfill. Most of the proposed "new" alternatives are distributed on the right half of Figure 3-23 indicating that projected impacts to environmental resources associated with these alternatives is high.

FINAL.ANA Chart 4

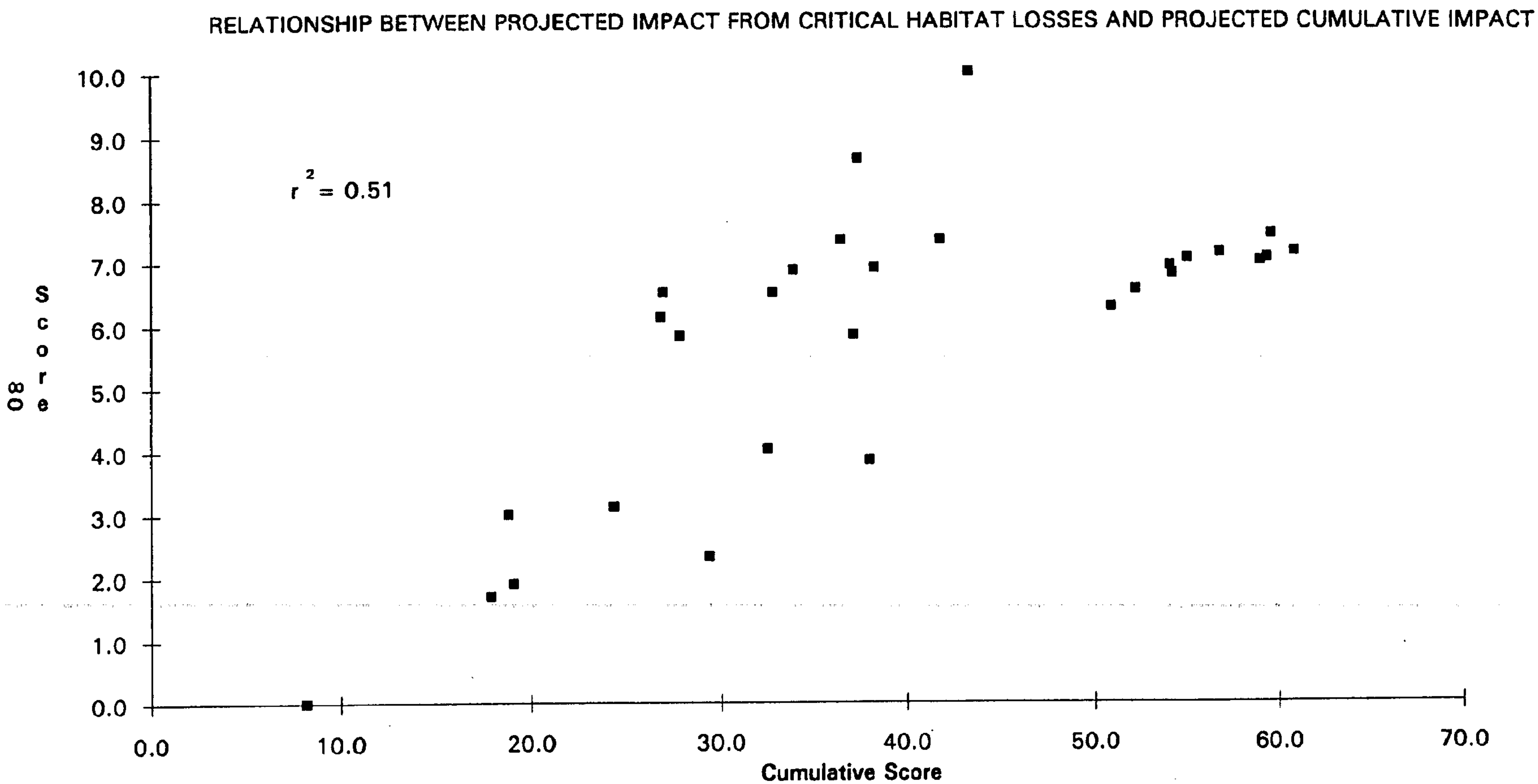


Figure 3-21. **Relationship between projected impacts of critical habitat losses and projected cumulative environmental impact.**

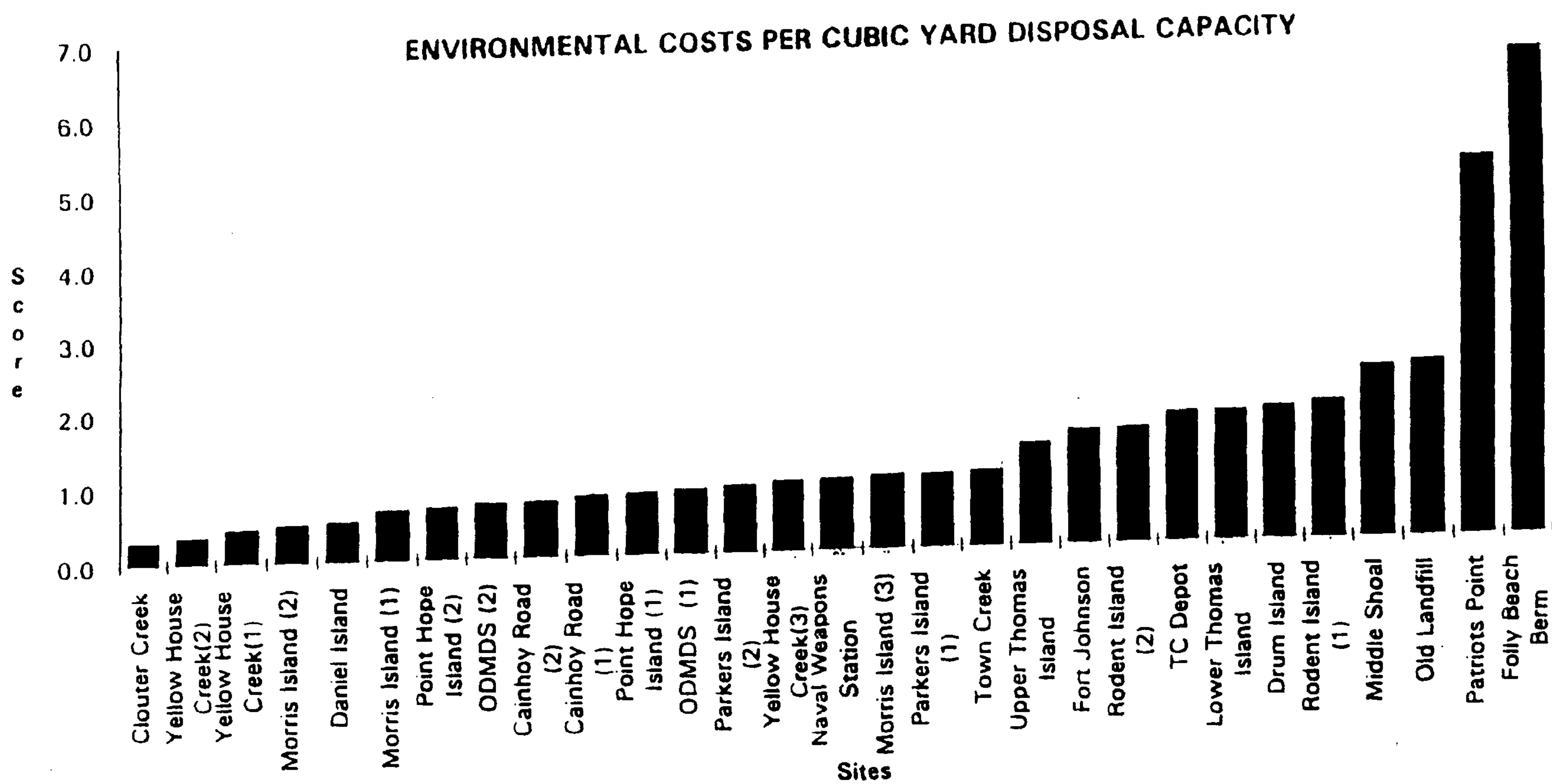


Figure 3-22. **Projected cumulative environmental impacts adjusted for capacity.**

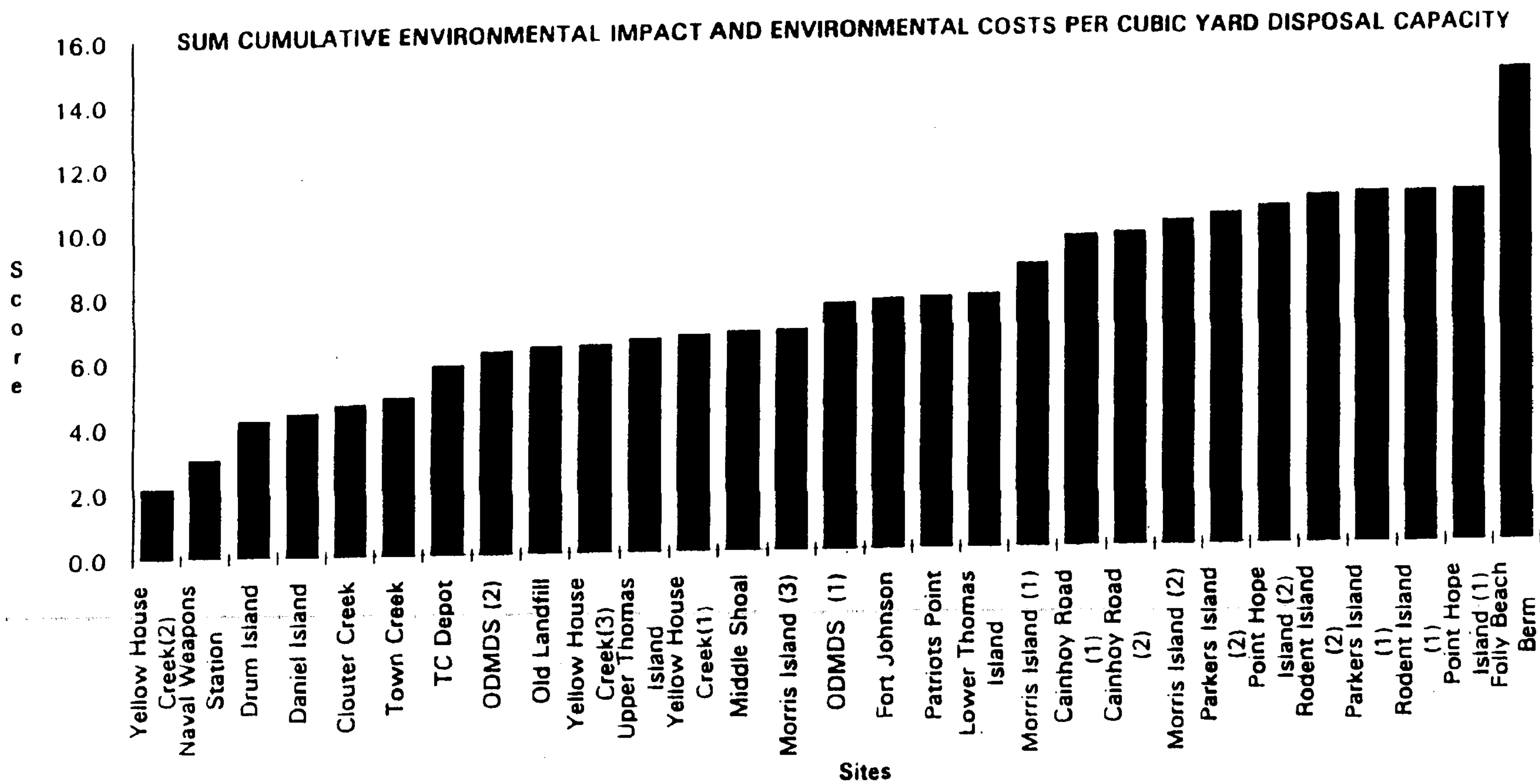


Figure 3-23. Sum cumulative environmental impacts and environmental costs per cubic yard disposal capacity.

The best of the proposed "new" alternatives from an environmental view point are Town Creek, Yellow House Creek alternative 3, and Upper Thomas Island. The least acceptable of the proposed "new" alternatives is the Folly Beach Berm. It not only was projected to have high cumulative environmental impact, it also was projected to have high environmental costs per cubic yard.

Chapter 4

Conclusions and Recommendations

- Charleston Harbor is one of the most valuable economic and national defense resources in South Carolina. It is also a valuable natural resource that provides spawning and nursery grounds for recreationally and commercially important fish and shellfish, and is extensively used by recreational fishermen and boaters. The maintenance of navigational channels and turning basins and development of port facilities in Charleston Harbor is critical to the regional economy and national security.

- The southern tip of Daniel Island has been used as a disposal site for a large portion of the dredged material removed from Charleston Harbor for the last decade. Plans to develop Daniel Island may make it unavailable as a dredged material disposal site in the future. These plans will adversely affect the regional economy, unless alternatives to the use of Daniel Island which have acceptable environmental impacts and economic costs can be identified.

- Twenty-nine alternatives to the use of Daniel Island were identified. Alternatives had a disposal capacity ranging from about one million to about 120 million cubic yards. The areal extent of alternatives ranged from 49 to over 9,800 acres. Alternatives represented a broad range of environmental conditions, including uncontained ocean disposal sites, diked estuarine disposal sites, and diked upland disposal sites. The list of alternatives is representative of the range of environmental conditions that exist in Charleston Harbor.

- A broad range of environmental concerns were identified as being associated with the construction and operation of dredged material disposal facilities in Charleston Harbor. The degree and extent of adverse effects for many of these concerns were associated with the areal extent over which existing land-use/habitat-cover patterns were altered. The habitat-cover information developed for alternative disposal sites was a valuable technical resource for identifying and evaluating potential environmental impacts. Although combining upland land uses into a single category had no adverse effect on the analyses conducted for this study, the resource maps which were produced might have been more useful if all the upland habitats had been shown. More detailed maps can be produced in the future using currently available data.

- None of the alternative sites were preferred habitat for threatened or endangered species or blocked migrational routes for recreationally and commercially important species. Threatened and endangered (T & E) plants have the potential to occur at several sites (i.e., Point Hope Island and Cainhoy Road). A detailed T&E evaluation will be required for these sites if they are identified as preferred alternatives to Daniel Island, or if they become a part of the long-term dredged material disposal strategy for Charleston Harbor.

- MRD developed measures (i.e., indicators) for projecting impacts associated with development of alternatives that used habitat-cover data and a matrix-based analytical approach. Analytical methods developed were:

    -- quantitative and objective,

    -- easy to conduct,

    -- not adversely affected by small changes in assumptions or inputs,

    -- reliable and repeatable,

    -- facilitated evaluation of broad range of scenarios, and

    -- easy to understand.

  Other elements of the Daniel Island Alternatives Study should seek similar attributes in the analytical approaches employed.

- The final assessment endpoint which was developed defined alternative dredged material disposal sites for Charleston Harbor that had both small cumulative environmental impacts and small environmental costs per cubic yard. Alternatives projected to represent the least threat to environmental resources were existing dredged material disposal sites including Yellow House

Creek alternative 2, Naval Weapons Station, Drum Island, Clouter Creek, and ODMDS alternative 2. Previously used dredged material disposal sites including TC Depot and Old Landfill also represent relatively small risks to environmental resources. These existing disposal facilities are acceptable alternatives to the use of Daniel Island. The combined disposal capacity of these existing facilities is over 240 million cubic yards, and in combination they provide most of the dredged material disposal capacity required for Charleston Harbor for the next 50 years.

- The most promising of the "new" sites evaluated were Town Creek, Yellow House Creek alternative 3, and Upper Thomas Island. Projections of low environmental impact for Town Creek and Yellow House Creek alternative 3 are problematical (Figure 3-22). Development of Yellow House Creek would result in loss of 322 acres of estuarine wetlands and 24 acres of small tidal creeks (Table 3-3). Development of Town Creek would block a major migrational route for biota (e.g., shrimp, fish, and crabs) into the Cooper River. Projections of low impact from these alternatives resulted because of the small impacts they were projected to have on existing environmental quality, water quality, adjacent environments, materials cycling, groundwater resources, and cultural resources. The projected low impacts for these environmental concerns clearly overwhelmed the projected impacts on critical habitat loss and migration and movement. Of the proposed "new" candidate sites, Upper Thomas Island appears to be the most reasonable. Development of Upper Thomas Island would provide an additional disposal capacity of about 25 million cubic yards. This is roughly equivalent to the disposal capacity that would result from development of Town Creek or Yellow House Creek alternative 3.

- The high projected impacts for Morris Island alternatives (i.e., alternative 3) was surprising. These high projections were mainly due to: (1) projected impacts on cultural resources, (2) projected impacts on groundwater resources, and (3) impacts on existing environmental quality (Table 3-18). Scores for these concerns accounted for 44 to 59 percent of the total score for Morris Island alternatives. This finding suggests that proposed expansions to the existing Morris Island site are not likely to be acceptable from an environmental viewpoint and need to be carefully evaluated.

- The vast majority of the candidate sites do not warrant further evaluation as alternatives to Daniel Island or for development of a long-term dredged material disposal strategy for Charleston Harbor. The list of sites that do not warrant further evaluation includes: the proposed Folly Beach Berm, Patriots Point, Middle Shoal, Rodent Island alternatives, Lower Thomas Island, Fort Johnson, Cainhoy Road alternatives, Point Hope Island alternatives, and Parkers Island alternatives.

- The Folly Beach berm was determined to be a particularly poor alternative to Daniel Island. This site had large cumulative environmental impacts, and the environmental cost/benefit ratio (i.e., projected impacts per cubic yard disposal capacity) was much higher than any other site.

- The most environmentally acceptable strategy for obtaining additional disposal capacity for Charleston Harbor would be to develop Upper Thomas Island. This would result in about 25 million cubic yards of additional capacity in a location near the center of Charleston Harbor.

References

Allen, K.O. and J.W. Hardy. 1980. Impacts of navigational dredging on fish and wildlife: A literature review. United States Fish and Wildlife Service, Biological Services Program. FWS/B8-80/07.

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper 964. United States Government Printing Office, Washington, DC.

Bara, M.O., R.W. Tiner, and D.C. Newkirk. 1977. Guidelines for evaluating proposed wetlands alterations in South Carolina. South Carolina Wildlife and Marine Resources Department, Columbia, SC.

Beaulac, M.N. and K.R. Reckhow. 1982. An examination of land use - nutrient export relationships. Water Resources Bulletin 18: 1013-1024.

Brockington and Associates, Inc. 1992. A cultural resources reconnaissance of possible dredged spoil disposal sites, Charleston Harbor, South Carolina. Prepared for the South Carolina Coastal Council and the United States Army Corps of Engineers by Brockington and Associates, Inc., Charleston, SC.

Brooks, M.J. and J.D. Scurry. 1979. An intensive archaeological survey of Amoco Reality property in Berkeley County, South Carolina with a test of two subsistence hypotheses for the prehistoric period. University of South Carolina Institute of Archaeology and Anthropology, Research Manuscript Series 147, Columbia, SC.

Butler, R.W., W.A. Nelson, and T.A. Henwood. 1987. A trawl survey method for estimating loggerhead turtle, *Caretta caretta*, abundance in five eastern Florida channels and inlets. Fish. Bul. 85: 447-453

Campbell, C.A. 1988. Nomination of Charleston Harbor South Carolina for selection to the National Estuary Program. Prepared by South Carolina Department of Health and Environmental Control for the United States Environmental Protection Agency, National Estuary Program, Washington DC.

Chamberlain, W.D. 1991. Habitats of the Charleston Harbor estuary. Prepared for the Charleston Harbor Estuary Committee, South Carolina Sea Grant Consortium, Charleston, SC.

Cowardin, L.M., V. Carter, F.E. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. United States Fish and Wildlife Service, Biological Services Program, Washington DC.

Dangermond, J. 1988. A review of digital data commonly available and some of the practical problems of entering them into a GIS. Proceedings 1988 ACSM-ASPRS Annual Convention, St. Louis, MO. Vol. 5:1-10.

Davis, K.B. and R.F. Van Dolah. 1992. Characterization of the physical, chemical, and biological conditions and trends in Charleston Harbor estuary: 1970-1985. *In*: *Characterization of the Physical, Chemical and Biological Conditions and Trends in Three South Carolina Estuaries: 1970-1985*. Vol. I, South Carolina Sea Grant Consortium, Charleston, SC.

Dickerson, D.D., J.I. Richardson, J.S. Ferris, A.L. Bass, and M. Wolf. 1991. Entrainment of sea turtles by hopper dredges in Cape Canaveral and King's Bay ship channels. United States Army Corps of Engineers Information Exchange Bulletin.

Ehrhart, L.M. 1987. Marine turtle mortality in the vicinity of Port Canaveral, Florida, 1977-84. pp. 1-65. *In*: W.N. Witzell (ed.), *Ecology of East Florida Sea Turtles*. NOAA Technical Report NMFS 53.

Florida Department of Transportation. 1985. Florida land use, cover and forms classification system. Second Edition, Procedures No. 550-010-001-a, Florida Department of Transportation, State Topographic Bureau, Thematic Mapping Section, Gainsville, FL.

Gosselink, J.G. and L.C. Lee. 1987. Cumulative impact assessment principles. Center for Wetland Resources Report LSU-CEI-86-08. Louisiana State University, Baton Rouge, LA.

Hirsch, A. 1988. Wetlands ranking - an innovative approach to wetland regulation? pp. 373-381. *In*: Hook E. (ed.), *The Ecology and Management of Wetlands*. Timber Press, Portland, OR.

Hockensmith, B.L. 1992. Letter to the United States Army Corps of Engineers, Charleston District (Mark Nelson) dated October 5, 1992 from the South Carolina Water Resources Commission.

Jensen, J.R. 1989. Remote sensing and geographic information system inputs to environmental sensitivity index mapping in the coastal zone. Paper presented at the Association of American Geographers Annual Meeting. Baltimore, MD. University of South Carolina, Department of Geography, Columbia, SC.

Kjerfve, B. 1976. The Santee-Cooper: A study of estuarine manipulation. pp. 45-56. *In*: M. Wiley (ed.)., *Estuarine Processes*. Vol. 1. Academic Press, NY.

Lacy, R.B., P. Beatty, D. Lin, and J.J. Jensen. 1991. The challenge of producing an accurate statewide land cover classification of digital satellite data. Proceedings of ACSM/ASPRS Annual Convention. Washington, DC.

Latham, P.J., L.G. Pearlestine, and W.M. Kitchens. 1987. Plant patterns and distribution of a South Atlantic coastal tidal marsh. Paper presented at the Eighth Annual Meeting of the Society of Wetland Scientists. Seattle, WA.

Limberg, K.E., C.C. Harwell, and S.A. Levin. 1984. Principals of estuarine impact assessment: Lessons learned from the Hudson River and other estuarine experiences. Ecosystems Research Center, Carson Hall, Cornell University, Ithaca, NY.

Morton, J.W. 1977. Ecological effects of dredging and spoil disposal: A literature review. United States Department of Interior, Fish and Wildlife Service, Technical Paper No. 94.

Moore, C. and W.D. Chamberlain. 1991. Fisheries of Charleston Harbor. Prepared for the Charleston Harbor Estuary Committee, South Carolina Sea Grant Consortium, Charleston, SC.

National Marine Fisheries Service. 1991. Biological opinion: Dredging of channels in the Southeastern United States from North Carolina through Cape Canaveral, Florida. Submitted to the United States Army Corps of Engineers by the National Marine Fisheries Service, Washington, DC.

Nelson, M. personal communication. United States Army Corps of Engineers, Charleston District, Charleston, S.C.

Nixon, S.W. 1986. Nutrient dynamics and productivity of marine coastal waters. pp. 97-115 *In:* R. Halnagy, D. Clayton, and M. Behbehani (eds.), *Marine Environment and Pollution*, The Alden Press, Oxford.

Nixon, S.W. and M. Pilson. 1983. Nitrogen in estuarine and coastal marine ecosystems. pp. 565-648 *In:* E.J. Carpenter and D.G. Capone (eds.), *Nitrogen in the Marine Environment*, Academic Press, NY.

Sandifer, P.A., J.V. Miglarese, D.R. Calder, J.J. Manzi, L.A. Barclay. 1980. Ecological characterization of the sea island coastal region of South Carolina and Georgia. Volume III. Prepared by the South Carolina Marine Resources Division for the United States Fish and Wildlife Service, Washington DC.

Schubel, J.R. and H.H. Carter. 1984. The estuary as a filter for fine-grained suspended sediment. pp. 81-106 *In:* V.S. Kennedy (ed.), *The Estuary as a Filter*, Academic Press, NY.

Shealy, M.H., J. Miglarese, and E.B. Joseph. 1974. Bottom fishes of South Carolina estuaries - relative abundance, distribution and length-frequency distribution. South Carolina Marine Resources Center, Tech. Rept. No. 6.

South Carolina Department of Health and Environmental Control (DHEC). 1990. Water classifications and standards: Regulation 61-68. South Carolina Department of Health and Environmental Control, Office of Environmental Quality Control, Columbia, SC.

South Carolina Water Resources Commission (WRC). 1990. A plan for measurement and mapping of the significant natural resources of the Edisto River basin, South Carolina. Report prepared for the National Oceanic and Atmospheric Administration, National Ocean Services by the South Carolina Water Resources Commission, Columbia, SC.

South, S.A. and M. Hartley. 1985. Deep water and high ground: seventeenth century low country settlement. pp. 263-286. *In*: R.S. Dickens and H.T. Ward (eds.). *Structure and Process in Southeastern Archaeology*. University of Alabama Press, Birmington, AL.

State Ports Authority (SPA). 1989. Port of Charleston Encyclopedia. South Carolina State Ports Authority, Charleston SC.

SPA. 1992. Port of Charleston fact sheet. South Carolina State Ports Authority, Charleston, SC.

Tiner, R.W. 1977. An inventory of South Carolina's coastal marshes. South Carolina Marine Resources Center Technical Report No. 23. South Carolina Wildlife and Marine Resources Department, Charleston, SC.

United States Environmental Protection Agency (USEPA). 1990. National water quality inventory. EPA 440-4-90-003. United States Environmental Protection Agency, Office of Water, Washington, DC.

United States Geological Survey. 1984. Land use and land cover digital data. Geological Survey Circular 85-E, National Cartographic Information Center, Reston, VA.

Van Dolah, R.F., P.H. Wendt, and E.L. Wenner. 1990. A physical and ecological characterization of the Charleston Harbor estuarine system. Prepared by the South Carolina Marine Resources Division for the South Carolina Coastal Council, Charleston, SC.

Van Dolah, R.F., P.P. Maier, S.R. Hopkins-Murphy, G.F. Ulrich, and D.M. Cupka. 1992. A survey of turtle populations in the Charleston Harbor entrance channel. Final Report submitted by the South Carolina Wildlife and Marine Resources Department to the United States Department of Interior, Fish and Wildlife Service, under Agreement No. 14-16-0004-90-944. South Carolina Marine Resources Research Institute, Charleston, SC.

Windom, H.L. 1976. Environmental aspects of dredging in the coastal zone. CRC Critical Reviews in Environmental Control 7: 91-109.

Winn, R.H., R.F. Van Dolah, A. Frankenburg, and T. Kanna. 1989. Benthic and sedimentological studies of the ocean dredged material disposal site for Charleston, South Carolina, Vol. I-II. Final report submitted to the United States Army Corps of Engineers, Charleston District, by the South Carolina Wildlife and Marine Resources Department under Agreement No. DACW60-87-H-0001. South Carolina Marine Resources Research Institute, Charleston, SC.

APPENDIX A

Description of Representative Important Biota

A. Reef Sponges and Corals

In the vicinity of Charleston Harbor, most reef sponges and corals are large relatively long-lived, slow-growing sessile invertebrates that inhabit hard substrates characterized by good water quality (Struhsaker 1969, Buchanan 1973, Parker et al. 1979, Powles and Barans 1980, Wenner 1983, Sedberry and Van Dolah 1984, Wenner et al. 1984, Wendt et al. 1985, and Stender et al. 1991). As they grow and mature, many of these biota produce plant-like structures that extend up to 1 m off the bottom. These structures modify the physical environment and increase habitat complexity. The complex and heterogenous environmental setting that results supports diverse and abundant fish and crab populations and is generally referred to as live bottom habitat. Dominant biota composing the reef sponge coral community in the vicinity of Charleston Harbor include the large sponges (e.g., *Ircinia compana, I. ramosa, Homaxinella sp., H. waltonsmithi, Halicona virgulata, Speciospongia vesparum,* and *Cliona spp.*), octocorals (e.g., *Titanidium frauenfeldi, Leptogorgia virgulata, Lophogorgia* sp., and *Muricea pendula*), and hard corals (e.g., *Deulina varicosa* and *Solenestrea hyades*). An abundant and diverse community of smaller invertebrates that serves as prey for large fish and crabs are associated with reef sponges and corals (Wendt et al. 1985). Reef sponges and corals are an appropriate Representative Important Biota (RIB) for evaluating the potential impacts of dredged material disposal on coastal habitats because they are critical to the formation and maintenance of habitats that favor the accumulation of recreationally and commercially important fish. In addition, they are intolerant to environmental perturbations that may be associated with dredged material disposal operations in coastal environments.

<u>Economic Value</u>:

Reef sponges and corals have little direct economic value. Habitats where these biota are abundant, however, favor the aggregation of recreationally and commercially important fish including various snappers, groupers, mackerels, and other gamefish (Parker et al. 1979, Powles and Barans 1980, Sedberry and Van Dolah 1984). As a result, commercial fishing vessels, "headboats", and recreational fishermen in coastal South Carolina routinely visit live bottom habitats. Commercial map products have been created that provide fishermen the coordinates for known live bottom areas.

<u>Distribution and Ecology</u>:

The sponges and corals or live bottom community is best developed and most abundant in water depths greater than 18 m that have exposed rocky outcrops and a high degree of bottom relief (e.g., Parker et al. 1979, Wenner et al. 1984, Van Dolah et al. 1987). Scattered live bottom habitat also occurs in shallow water, some "almost up to the beach" (Parker et al. 1979). The abundance of "live bottom" habitat has been estimated by this study to comprise from 5-15 percent of the bottom area of the present Ocean Dredged Material Disposal Site (ODMDS).

Once established, sponge and coral populations and associated communities are relatively stable exhibiting a small amount of seasonal variation in the abundance and mass of dominant organisms (Wenner 1983, Wenner et al. 1984).

Potential Impacts of Dredged Material Disposal:

The abundance of the large sponges and soft corals are dependent upon the availability of hard substrate for attachment. Although the substrate need not be exposed, few sponges or corals occur when the overburden of sediment is greater than 5-8 cm deep (SCWMRD 1984). The overwhelming majority of sponges and corals grow in habitats where the veneer of sediments covering the hard substrate used for attachment is <5 cm deep. Activities, such as ocean disposal of dredged material which increase the sediment overburden and decrease the amount of exposed hard substrate, are detrimental to the growth and recruitment of sponges and corals. In addition, increased turbidity and suspended sediment loads from dredged disposal activities may adversely impact feeding processes. Because most of the sponges and corals are relatively long-lived, their populations are slow to recover from perturbations, like disposal of dredged material, that cause high mortality.

References:

Buchanan, C.C. 1973. Effects of an artificial habitat on the marine sport fishery and economy of Murrells Inlet, South Carolina. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 35(9): 15-22.

Parker, R.O.,Jr., R.B. Stone, and C.B. Buchanan. 1979. Artificial reefs off Murrells Inlet, South Carolina. Mar. Fish. Rev. 41: 12-24.

Powles, H., and C.A. Barans. 1980. Groundfish monitoring in sponge-coral areas off the southeastern United States. Mar. Fish. Rev. 42(5): 21-35.

Sedberry, G.R. and R.F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the U.S.A. Env. Biol. Fish. 11(4): 241-258.

South Carolina Wildlife and Marine Resources Department. 1984. South Atlantic OCS area living marine resources study. Phase III. Vol. I. Final report prepared for the Minerals Management Service under contract 14-12-0001-29185. 223pp.

Stender, B.W., R.F. Van Dolah, P.P. Maier. 1991. Identification and location of live bottom habitats in five potential borrow sites of Myrtle Beach S.C. Final Report submitted to U.S. Department of Interior Fish and Wildlife Service under agreement no. 14-16-0004-91-907.

Struhsaker, P. 1969. Demersal fish resources: Composition, distribution, and commercial potential of the continental shelf stocks off the southeastern United States. U.S. Fish. Wildl. Serv., Fish. Ind. Res. 4: 261-300.

Van Dolah, R.F., P.H. Wendt, and N. Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research (5): 39-54.

Wendt, P.H., R.F. Van Dolah, and C.B. O'Rourke. 1985. A comparative study of the invertebrate macrofauna associated with seven sponge and coral species collected from the South Atlantic Bight. J. Elisha Mitchell Soc. 101(3): 187-203.

Wenner, C.A. 1983. Species associations and day-night variability of trawl caught fishes from the inshore sponge-coral habitat, South Atlantic Bight. U.S. Fish. Bull. 81: 532-552.

Wenner, E.L., P. Hind, D.M. Knott, and R.F. Van Dolah. 1984. A temporal and spatial study of invertebrate communities associated with hard bottom habitats in the South Atlantic Bight. NOAA NMFS Tech. Rep. 18. 104pp.

B. Sea Oats

Sea Oats (*Unicola paniculata*) is instrumental in the formation, maintenance,and growth of coastal dunes (Birkemeier et al. 1984), and the dune environment formed by sea oats provides habitat for a unique assemblage of biota, including nesting areas for threatened and endangered sea turtles. Dune habitats also protect inland areas, particularly homesites, from erosion associated with storms (Hester and Mendelssohn 1991). Because of the key role of sea oats in dune formation and maintenance, this species is considered a keystone species for development and maintenance of dune environments and is an appropriate Representative Important Biota (RIB) for defining and evaluating the potential impacts of construction and operations of dredged material disposal facilities on the marine environment.

<u>Economic Value</u>:

Although sea oats have no direct economic value, the presence of established dune habitat reduces the risks of adjacent upland environments to damage from storm events. The presence of sea oats therefore makes beachfront property that contain well developed sea oat communities of higher value to humans.

Distribution and Ecology:

Sea oats are found on coastal dunes (Pinson 1973, Gaddy 1977) from Virginia to Florida (Woodhouse et al. 1968). This species thrives in environments that are exposed to high wind velocity with attendant salt spray, high evapotranspiration, and substantial sand movement and deposition (Oosting and Billings 1942, Wagner 1964, Hester and Mendelssohn 1989). Sea oats attains its greatest abundance on the foredunes (Stalter 1974) where the nutrients required for growth are abundant from salt spray and materials in the newly deposited sand (Wilson 1959, Clayton 1972, Van der Valk 1974, Hester and Mendelssohn 1991). Sea oats are intolerant to environmental modifications that reduce the amount of salt spray and sand deposition.

Sea oats colonize bare sands through dispersal of seeds (Wagner 1964, Hosier 1975) and vegetative growth of the rhizomes (Wagner 1964). Mature seeds are dispersed in the winter by the wind, and seeds that were buried under 5 to 10 cm of sand in favorable environments germinate the following spring (Wagner 1964). Vegetative growth is confined to established stands of sea oats located in the foredunes (Wagner 1964, Woodhouse et al. 1968, Hester and Mendelssohn 1991).

The coastal dune community is a seed- and grass-rich environment that provides foraging and nursery habitat for many coastal birds including doves, sparrows, and blackbirds (Sandifer et al. 1980). Raptors and insectivorous birds prey on the insects, birds, and small mammals that forage and nest in sea oats. Sea turtles use dune habitats along South Carolina barrier islands as nesting habitat.

Potential Impacts of Dredged Material Disposal:

The most serious threat to sea oats from disposal of dredged material is the direct loss of habitat by the conversion of established dune habitat into disposal areas. The hydric to mesic soil conditions that characterize disposal areas prevent the re-establishment of sea oats and the associated flora and fauna.

References:

Birkemeier, W., R. Dolan, and N. Fish. 1984. The evolution of a barrier island: 1930-1980. Shore and Beach 52(2): 3-12.

Clayton, J.L. 1972. Salt spray and mineral cycling in two California coastal ecosystems. Ecology 52: 74-81.

Gaddy, L.L. 1977. A physiographic and vegetational study of brown pelican nesting habitat on Deveaux Bank, S.C. South Carolina Wildlife and Marine Resources Department, Division of Wildlife and Freshwater Fisheries, Columbia. 26 pp. (unpubl.)

Hester, M.W. and I.A. Mendelssohn. 1989. Water relations and growth responses of *Uniola paniculata* (sea oats) to soil moisture and water-table depth. Ecologia 78: 289-296.

Hester, M.W. and I.A. Mendelssohn. 1991. Expansion patterns and soil physicochemical characterization of three Louisiana populations of *Uniola paniculata* (sea oats). Journal of Coastal Research 7(2): 387-401.

Hosier, P.E. 1975. Dune and marsh vegetation. Pages D 1-96 <u>in</u> Environmental Research Center, Inc. Environmental Inventory of Kiawah Island. Prepared for Coastal Shores, Inc.

Oosting, H.J and W.D. Billings. 1942. Factors effecting vegetational zonation on coastal zones. Ecology 23(2): 131-142.

Pinson, J.N., Jr. 1973. A floristic analysis of open dunes in South Carolina. Ph.D. dissertation, University of South Carolina, Columbia.

Sandifer, P.A., J.V. Miglarese, D.R. Calder, J.J. Manzi, and L.A. Barclay. 1980. Ecological Characterization of the sea island coastal region of South Carolina and Georgia, Volume III: Biological features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/42. 620 pp.

Stalter, R. 1974. Vegetation in coastal dunes of South Carolina. Castanea 39: 95-103.

Van der Valk, A.G. 1974. Mineral cycling in coastal foredune plant communities in Cape Hatteras National Seashore. Ecology 55: 1349-1358.

Wagner, R.H. 1964. The ecology of *Uniola paniculata* L. in the dune-strand habitat of North Carolina. Ecological Monographs 34(1): 79-96.

Wilson, A.T. 1959. Surface of the ocean as a source of air-borne nitrogenous material and other plant nutrients. Nature (London) 184: 99-101.

Woodhouse, W.W., E.D. Seneca, and A.W. Cooper. 1968. Use of sea oats for dune stabilization in the southeast. Shore and Beach 36: 15-21.

C. Smooth Cordgrass

Smooth cordgrass (*Spartina alterniflora*) is an appropriate Representative Important Biota for defining and evaluating the potential impacts of the alternatives dredged material disposal sites because:

- This species has a major role in the material and energy cycle for estuarine habitats (Darnell 1967).
- Wetland habitats composed of this species are used as a nursery by early life stages of many commercially and recreationally important fish and birds (Chabreck et al. 1982, Mense and Wenner 1989, Wenner et al. 1990, Stender and Martore 1990).
- Many species of wading birds (e.g., herons) rely upon wetlands composed of smooth cordgrass as foraging habitat.
- The roots and stems of smooth cordgrass are important in stabilizing shorelines and reducing erosion (Woodhouse et al. 1974).
- Marshes composed of smooth cordgrass provide scenic vistas that are highly valued by the public.

Because of the key role of smooth cordgrass in estuarine material cycles and food web dynamics, it is often considered a "keystone" species for estuaries.

Economic Value:

Smooth cordgrass has little direct economic value. However, the multimillion dollar recreational fishing and commercial shrimping industries of the Southeast Atlantic rely upon marshes dominated by smooth cordgrass to provide nursery habitat for early developmental stages of these biota. In addition, shorelines dominated by smooth cordgrass are highly desired as homesites because of the reduced potential for erosion and scenic vistas.

Distribution and Ecology:

Smooth cordgrass is the dominant vegetation in higher salinity tidal marshes from northern Florida to Maine (Reimold 1977). This species attains its greatest abundance and productivity in the lower elevation marsh zone (Woodhouse et al. 1974, Lagna 1975, McKee and Patrick 1988). The distribution and abundance of smooth cordgrass in low elevation salt marshes in Charleston Harbor are mainly influenced by salinity. In areas with an average salinity of 20 ppt or greater, such as along Wando River and in the protected waters between Fort Johnson and Morris Island, large monoculture stands of smooth cordgrass are found. However, in areas with an average salinity of ≤ 10 ppt, such as in the Cooper River, smooth cordgrass co-occurs with needlerush (*Juncus romerianus*). Needlerush survives in the low elevation marsh zone when the salinity is ≤ 10 ppt (Wiegert and Freeman 1990). As very low salinity (< 1 ppt), such as in the upper portions of the Cooper River near the Yellow House Creek site, smooth cordgrass is almost completely replaced by needlerush and cattail (*Typha* sp.).

Smooth cordgrass exhibits considerable heterogeneity in height and productivity depending upon environmental conditions. Three relatively distinct forms occur: tall, medium, and short (Mooring et al. 1971, Shea et al. 1975). The tall form may have an annual production 2-4 times greater than the medium and short forms (Keefe 1972, Turner 1976). Many factors control the growth form of smooth cordgrass including soil concentrations of salinity (Smart and Barko 1978, Webb 1983), dissolved oxygen concentration, nitrogen concentration (Linthurst and Seneca 1981), sulfide levels (King et al. 1982), and the availability of iron (Adams 1963). In established stands of smooth cordgrass, the primary mode of reproduction is by means of rhizomes (Woodhouse et al. 1968). Seed dispersal is the primary mode for establishing "new" stands of cordgrass.

Estuarine wetlands dominated by smooth cordgrass serve as nursery grounds for many aquatic invertebrates, including crabs and shrimp (Mense and Wenner 1989, Wenner et al. 1990, Stender and Martore 1990) as well as fishes, such as red drum, spotted seatrout, and spot (Chabreck et al. 1982, Mense and Wenner 1989, Wenner et al. 1990, Stender and Martore 1990). It is also an important foraging habitat for wading birds, such as the great blue heron, and terrestrial mammals, such as the raccoon. Smooth cordgrass also plays a key role in the estuarine material cycles and food web dynamics, and is the dominant source of detritus supporting the complex food web of estuaries adjacent to salt marshes (e.g., Teal 1958).

<u>Potential Impacts of Dredged Material Disposal</u>:

The most serious threat to smooth cordgrass from operation of dredged material disposal facilities is the conversion of habitats dominated by this species into dredged material disposal areas. Environmental conditions in disposal areas do not favor reestablishment of smooth cordgrass because elevation and water movement patterns are severely altered. In addition, the "new" environment that is created inside spoil disposal areas does not provide a habitat that can function as a nursery for commercially and recreationally important fish and crustaceans. The "new" habitat also has a much reduced role in material and energy cycles.

References:

Adams, D.A. 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. Ecology 44(3): 445-456.

Chabreck, R.H., J.E. Holcombe, R.G. Linscombe, and N.E. Kinler. 1982. Winter foods of river otters from saline and fresh environments in Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36: 473-483.

Darnell, R.M. 1967. Organic detritus in relation to the estuarine ecosystem. Pages 376-382 in G.H. Lauff (ed.). Estuaries. Am. Assoc. Adv. Sci., Publication No. 83, Washington, DC.

Keefe, C.W. 1972. Marsh production: A summary of the literature. Contributions in Marine Science 16: 164-181.

King, G.M., M.J. Klug, R.G. Wiegert, and A.G. Chalmers. 1982. Relation of soil water movement and sulfide concentration to *Spartina alterniflora* production in a Georgia salt marsh. Science 218: 61-63.

Lagna, L. 1975. The relationship of *Spartina alterniflora* to mean high water. State University of New York, Marine Sciences Research Center, Stony Brook.

Linthurst, R.A and E.D. Seneca. 1981. Aeration, nitrogen and salinity as determinants of *Spartina alterniflora* Loisel. growth response. Estuaries 4(1): 53-63.

McKee, K.L. and W.H. Patrick, Jr. 1988. The relationship of smooth cordgrass (*Spartina alterniflora*) to tidal datums: a review. Estuaries 11(3): 143-151.

Mense, D.J. and E.L. Wenner. 1989. Distribution and abundance of early life history stages of the blue crab, *Callinectes sapidus*, in tidal marsh creeks near Charleston, South Carolina. Estuaries 12(3):157-168.

Mooring, M.T., A.W. Cooper, and E.D. Seneca. 1971. Seed germination response and evidence for height ecophenes in *Spartina alterniflora* from North Carolina. American Journal of Botany 58: 48-55.

Reimold, R.J. 1977. Mangals and salt marshes of eastern United States. Pg. 157-164 in V.J. Chapman (ed.). Wet coastal ecosystems of the world. Elsevier Science Publishing Co. Inc., New York.

Shea, M.L., R.S. Warren, W.A. Neiring. 1975. Biochemical and transplantation studies of the growth form of *Spartina alterniflora* on Connecticut salt marshes. Ecology 461-466.

Smart, R.M. and J.W. Barko. 1978. Influence of sediment salinity and nutrient on the physiological ecology of selected salt marsh plants. Estuarine and Coastal Marine Science 7: 487-495.

Stender, B.W. and R.M. Martore. 1990. Finfish and invertebrate communities. Pages 241-287 in R.F. Van Dolah, P.H. Wendt, and E.L. Wenner. 1990. A physical and ecological characterization of the Charleston Harbor estuarine system. South Carolina Wildlife and Marine Resources Department, Marine Resources Division, Charleston.

Teal, J.M. 1958. Distributions of fiddler crab in Georgia salt marshes. Ecology 39(2): 185-189.

Turner, R.E. 1976. Geographic variation in salt marsh macrophyte production: A review. Contributions in Marine Science 20: 47-68.

Webb, J.W. 1983. Soil water salinity variations and their effects on *Spartina alterniflora*. Contributions in Marine Science 26: 1-13.

Wenner, C.A., W.A. Roumillat, J.E. Moran, Jr., M.B. Maddox, L.B. Daniel, III, and J.W. Smith. 1990. Investigations on the life history population dynamics of marine recreational fishes in South Carolina: Part 1. S.C. Wildlife and Marine Resources Department, Marine Resources Division.

Wiegert, R.G. and B.J. Freeman. 1990. Tidal salt marshes of the southeast Atlantic coast: a community profile. U.S. Fish and Wildlife Service, Biological Report 85(7.29).

Woodhouse, W.W., E.D. Seneca, and A.W. Cooper. 1968. Use of sea oats for dune stabilization in the southeast. Shore and Beach 36: 15-21.

Woodhouse, W.W., Jr., E.D. Seneca, and S.W. Broome. 1974. Propagation of *Spartina alterniflora* for substrate stabilization and salt marsh development. North Carolina State University, Technical Memorandum No. 46.

D. The Loggerhead Turtle

The loggerhead turtle (*Caretta caretta*) is a large marine reptile which at various stages of its life cycle uses a variety of marine habitats in the vicinity of Charleston. This species was added to both the federal and state List of Threatened and Endangered Species in 1978 and is still considered threatened on both lists. Much debate has arisen in recent years over the protection and maintenance of the loggerhead turtle populations (Murphy and Murphy-Hopkins 1989). High turtle mortalities associated with shrimp trawling and hopper dredge operations are of particular concern. In addition, many programs to protect sea turtle nesting habitats have been initiated. Because of concerns over declining turtle populations, as well as this species' dependence upon beach-front habitats that are proposed for use as disposal areas for dredged material for successful reproduction, the loggerhead turtle is considered to be an appropriate threatened and endangered biota for use in evaluating the effects of construction and operations of dredged material disposal facilities on environmental resources.

<u>Distribution and Ecology</u>:

Loggerhead turtles are found circum-globally. They inhabit a variety of marine environments including coastal waters, bays, lagoons, and estuaries in temperate, sub-tropical, and tropical waters of the Atlantic, Pacific, and Indian oceans. In the Atlantic Ocean, hatchlings and juveniles apparently circulate within the North Atlantic gyre until they reach a size of about 40 cm, at which time they take up residence in lagoons, estuaries, bays, and river mouths (Dodd 1988). Favored aggregation areas along the U.S. southeast coast include Chesapeake Bay (Lutcavage and Musick 1985) and the Indian River lagoon system of Florida (Ehrhart 1983). Loggerhead turtles also congregate in channel habitats during summer and fall months including the Charleston Harbor channel (Van Dolah et al. 1992). Some of the loggerheads along the southeastern U.S. coast move northward in spring and southward again in autumn (Dodd 1988).

Loggerheads are gonochoristic, and the adults are sexually dimorphic (Dodd 1988). The most obvious differences between the sexes are the longer tail and recurved claws of the male (Hughes 1984). Both features apparently aid in mating. Loggerheads nest on ocean-front beaches well above the high-tide mark, often within vegetation behind the fore dune system (Carr 1952, Caldwell 1959). Low dunes backing a high beach are preferred nesting sites (Caldwell 1959). Nesting activity may be aborted as a result of human or animal disturbance, improper substrate characteristics, or improper or unexpected temperature cues (Dodd 1988). In South Carolina, nesting usually begins in mid-May, and lasts through mid-August (NMFS and USFWS 1991, Hopkins and Murphy 1984). Estimated age of loggerhead turtles at maturity is 13-15 years (Zug et al. 1983, 1986). Carapace lengths of mature females from the southeastern U.S. range from about 70 cm to over 124 cm with a mean of about 95 cm. Body mass of nesting females range from 80 to 180 kg, with a mean of 116 kg (Dodd 1988). Male loggerheads are about the same size as females (Dodd 1988).

Nest construction begins with the excavation of a body pit. The pit is scooped out with the hind flippers (Dodd 1988). Egg laying commences within seconds of nest completion. Eggs are laid singly or in groups of two or three. Clutch sizes in South Carolina range from 64-198, with an average size of 126 eggs (Caldwell 1959). Incubation period is inversely correlated with nest temperature (McGhee 1979). The mean incubation period in South Carolina is 55 days, and the hatching success is about 73 percent (Caldwell 1959).

Hatchlings remain in the nest for about 7 days (Dodd 1988). This nestling phase allows time for development to be completed. Hatchlings usually emerge from nests at night (Dodd 1988). Visual and geotropic clues guide hatchlings to the ocean where they engage in about 20 hours of non-stop swimming (Dodd 1988). Young loggerheads apparently spend the first 4-6 years of their life in the North Atlantic Gyre, drifting and feeding along the upwellings and convergences which concentrate food in the sparse oceanic environment (Carr 1986).

The loggerhead turtle feeds on a wide variety of bottom dwelling marine invertebrates. A preferred food in the southeastern U.S. is the horseshoe crab, *Limulus polyphemus* (Dodd 1988). Loggerheads also have been reported feeding on jellyfish near the surface (Dodd 1988). Hatchlings and juveniles feed on macroplanktonic food items entrained in drift lines and convergences (Carr 1987).

Adult loggerheads are large and well-armored animals, and have few predators. Large sharks, particularly tiger sharks (*Galeocerdo cuvieri*), are probably responsible for the missing flippers frequently observed and are probably a major predator (Dodd 1988). Hatchlings and juveniles are more vulnerable to shark attacks than adults. Hatchlings are preyed upon before reaching the water by ghost crabs (*Ocypode quadrata*), and during daylight hours, by a variety of birds. Other predators of hatchlings include racoons, foxes, dogs, and cats (Dodd 1988).

Potential Impacts of Dredge Material Disposal:

Loggerhead turtles sporadically occur in the Charleston Harbor estuarine system, except in the entrance channel where they consistently occur during spring, summer, and fall (Van Dolah et al. 1992). Establishment of dredged disposal material sites in the mid to upper reaches of the Harbor would therefore have few if any negative effects on loggerhead turtles. Disposal of dredged material in the vicinity of the Charleston Harbor entrance channel may, however, adversely affect loggerhead turtle populations residing there. Development of beachfront dredged material disposal sites (e.g., Morris Island) may also adversely affect nesting activities of loggerhead turtles (Nelson and Dickerson 1988).

References:

Caldwell, D.K. 1959. The loggerhead turtle of Cape Romain, South Carolina. (abridged and annotated manuscript of W.P. Baldwin, Jr. and J.P. Loftin, Jr.). Bull. Fla. State Mus. Biol. Sci. 4: 319-348.

Carr, A.F. Jr. 1952. Handbook of Turtles. The turtles of the United States, Canada,and Baja California. Cornell University Press. Ithaca, NY.

Carr, A.F. Jr. 1986. Fips, FADS and little loggerheads. Bioscience 36: 92-100.

Carr, A.F. Jr. 1987. Impact of nondegradeable marine debris on the ecology and survival outlook of sea turtles. Mar. Pollut. Bull. 18(6B): 352-356.

Dodd, C.K. Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). United States Fish Wildl. Biol. Rep. 88(14). 110p.

Ehrhart, L.M. 1983. A survey of nesting by the green turtle, *Chelonia mydas*, and the loggerhead turtle, *Caretta caretta*, in South Brevard County, Florida. Unpubl. Report to the World Wildl. Fund - U.S., Washington, DC. 49p.

Hopkins, S. and J. Richardson (eds.). 1984. Recovery plan for marine turtles. National Marine Fisheries Service, Washington, DC.

Hopkins-Murphy, S.R. and T.M. Murphy. 1984. Distribution of loggerhead turtle nesting activity in South Carolina by aerial beach survey. Study completion report, October 1, 1979 through September 30, 1982, E-1 Study No. V1-A-2. South Carolina Wildlife and Marine Resources Department. 60pp.

Hughes, G.R. 1984. Saving Tongaland's Turtles. Pages 91-103 In: P.J. Mundy (ed.), Proceedings of the symposium "The Extinction Alternative," 19-20 May, 1983, Pretoria.

Lutcavage, M. and J.A. Musick. 1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985: 449-456.

McGhee, M.A. 1979. Factors affecting the hatching success of loggerhead sea turtle eggs *Caretta caretta caretta*. Unpubl. M.S. Thesis. University of Central Florida, Orlando.

Murphy, T.M. and S.R. Hopkins-Murphy. 1989. Sea turtle and shrimp fishing interactions: A summary and critique of relevant information. Published by the Center for Marine Conservation, Washington, DC.

Nelson, D.A., and D.D. Dickerson. 1988. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpubl. Report. United States Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991. Recovery plan for U.S. population of loggerhead turtle. National Marine Fisheries Service, Washington, DC.

Van Dolah, R.F., P.P. Maier, S.R. Hopkins-Murphy, G.F. Ulrich, and D.M. Cupka. 1992. A survey of turtle populations in the Charleston Harbor entrance channel. Final Report prepared for: U.S. Department of the Interior, U.S. Fish and Wildlife Service under agreement No. 14-16-0004-90-944.

Zug, F.R., A. Wynn, and C. Ruckdeschel. 1983. Age estimates of Cumberland Island loggerhead sea turtles. Mar. Turtle newsl. 25: 9-11.

Zug, G.R. 1986. Age determination of loggerhead sea turtles, *Caretta caretta*, by incremental growth marks in the skeleton. Smithson. contrib. Zool. No. 427.

E. Red-Cockaded Woodpecker

The red-cockaded woodpecker (*Picoides borealis*) is a rare but permanent resident of upland habitats in the low country of South Carolina. This species was placed on the Federal Register of endangered species in 1970 because of declines in abundance associated with loss of preferred habitat (Murphey 1939, Sprunt and Chamberlain 1949). Because suitable habitat for the red-cockaded woodpecker potentially occurs in upland areas of some of the candidate dredged material disposal sites (e.g., Cainhoy Road, Parkers Island), it is an appropriate rare and endangered species to use for defining and evaluating the potential impacts of alternative dredged material disposal sites.

Distribution and Ecology:

The red-cockaded woodpecker is a non-migratory, endemic bird of upland pine forests of the southeastern U.S. (Hopkins and Lynn 1971, Baker 1982, Locke and Conner 1983) and prefers relatively pure stands of living pines with an open understory that are dominated by grasses, forbs, and low shrubs (DeLotelle et al. 1983, Wood 1983, Miller 1978, Ramey 1980, Hooper and Lennartz 1981, Hopkins and Lynn 1971, Grimes 1977, Locke 1980). Although pines are the preferred nesting and foraging habitat, red-cockaded woodpeckers will forage upon hardwoods (Ramey 1980) and cypress (DeLotelle et al. 1983). Red-cockaded woodpeckers avoid pine forests with dense hardwood understories (Van Balen and Doerr 1978, Wood 1983). In the 1800's, this species was abundant from New Jersey to Texas and inland as far as Tennessee (Audubon 1839). However, by the mid-1900 this species was abundant in only a few southeastern coastal states (USFWS 1985). Population declines were attributed to loss of suitable pine forest habitat (Wahlenber 1946, 1960, USFWS 1985).

Red-cockaded woodpeckers are colonial birds that generally occur as breeding pairs or in clans consisting of a breeding pair and the most recent offspring (Lennartz and Harlow 1979, Lennartz 1983). The foraging range for a clan ranges from 74-483 acres (Hooper et al. 1982). Reproductive success is related to the amount of suitable foraging habitat available. Pairs average about one young per nest in forest plots less than 100 acres in size, but almost three young per nest when the amount of foraging habitat exceeds 150 acres. About 125 acres of mature pine (>30 years old) and pine-hardwood stands provide adequate foraging resources for a clan of red-cockaded woodpeckers. The ecological role of the red-cockaded woodpecker is poorly understood. As a foraging insectivore, however, they probably contribute to control of insect populations, particularly pests, in pine and mixed pine-hardwood forests.

Potential Impacts of Dredge Material Disposal:

The most serious threat to red-cockaded woodpeckers associated with construction and operation of dredged material disposal sites, is the conversion of mature pine forests to dredge material disposal sites. In addition, infrequent excessive (≥90 decibels) noise and human activity lasting more than a few minutes near a colony during the nesting season could cause nesting failure (Jackson 1983).

References:

Audubon, J.J. 1839. Ornithological biography, Vol. 5. Edinburgh.

Baker, W.W. 1982. The distribution, status and future of the red-cockaded woodpecker in Georgia. Pages 82-87 in R.R. Odum and J.W. Guthrie (eds.). Proceedings of the Nongame and Endangered Wildlife Symposium. Georgia Department of Natural Resources, Game and Fish Division. Technical Bulletin WL 5.

DeLotelle, R.S., J.R. Newman, and A.E. Jerauld. 1983. Habitat use by red-cockaded woodpecker in central Florida. Pages 59-67 in D.A. Wood (ed.). Proceedings of the Symposium on the Ecology and Management of Red-cockaded Woodpecker, II. Florida Game and Fresh Water Fish Commission, U.S. Fish and Wildlife Service.

Grimes, T.L. 1977. Relationships of red-cockaded woodpecker (*Picoides borealis*) productivity to colony area characteristics. M.S. thesis, Clemson University, South Carolina.

Hooper, R.G. and M.R. Lennartz. 1981. Foraging behavior of the red-cockaded woodpecker in South Carolina. The Auk 98: 321-324.

Hooper, R.G., L.V. Niles, R.F. Harlow, and G.W. Wood. 1982. Home ranges of red-cockaded woodpeckers in coastal South Carolina. The Auk 99: 675-682.

Hopkins, M.L. and T.E. Lynn, Jr. 1971. Some characteristics of red-cockaded woodpecker cavity trees and management implications in South Carolina. Pages 140-169 in R.L. Thompson (ed.). Proceedings of the Symposium on the Ecology and Management of Red-cockaded Woodpecker. Bureau of Sport Fishery and Wildlife and Tall Timbers Research Station, Tallahassee, Florida.

Jackson, J.A. 1983. Possible effects of excessive noise on red-cockaded woodpeckers. Pages 38-40 in D.A. Wood (ed.). Proceedings of the Symposium on the Ecology and Management of Red-cockaded Woodpecker, II. Florida Game and Fresh Water Fish Commission, U.S. Fish and Wildlife Service.

Lennartz, M.R. 1983. Sociality and cooperative breeding of red-cockaded woodpeckers (*Picoides borealis*). Ph.D. dissertation. Clemson University, Clemson, South Carolina.

Lennartz, M.R. and R.F. Harlow. 1979. The role of parent and helper red-cockaded woodpeckers at the nest. Wilson Bulletin 91: 331-335.

Locke, B.A. 1980. Colony site selection by red-cockaded woodpecker in east Texas. M.S. Thesis, Austin State University, Texas.

Locke, B.A. and R.N. Conner. 1983. A statistical analysis of the orientation of entrances to red-cockaded woodpecker cavities. Pages 108-109 in D.A. Wood (ed.). Proceedings of the Symposium on the Ecology and Management of Red-cockaded Woodpecker, II. Florida Game and Fresh Water Fish Commission, U.S. Fish and Wildlife Service.

Miller, G.L. 1978. The population, habitat, behavioral and foraging ecology of the red-cockaded woodpecker (*Picoides borealis*) in southeastern Virginia. M.A. Thesis. The College of William and Mary, Williamsburg, Virginia.

Murphey, E.E. 1939. Red-cockaded woodpecker, *Dryobates borealis borealis* (Vieillot) in A.C. Bent (ed.). Life histories of North American woodpeckers. Bulletin of the United States National Museum 174: 72-79.

Ramey, P. 1980. Seasonal, sexual, and geographical variation in the foraging ecology of red-cockaded woodpecker (*Picoides borealis*). M.S. Thesis, Mississippi State University, Mississippi State, Mississippi.

Sprunt, A., Jr. and E.B. Chamberlain. 1949. South Carolina bird life. University of South Carolina Press, Columbia.

U.S. Fish and Wildlife Service. 1985. Red-cockaded woodpecker recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

Van Balen, J.B. and P.D. Doerr. 1978. The relationship of understory to red-cockaded woodpecker activity. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32: 82-92.

Wahlenber, W.G. 1946. Longleaf pine - its use, ecology, regeneration, protection, growth, and management. School of Forestry, Duke University, Durham, North Carolina.

Wahlenber, W.G. 1960. Loblolly pine - its use, ecology, regeneration, protection, growth, and management. School of Forestry, Duke University, Durham, North Carolina.

Wood, D.A. 1983. Foraging and colony habitat characteristics of the red-cockaded woodpecker in Oklahoma Pages 51-58 in D.A. Wood (ed.). Proceedings of the Symposium on the Ecology and Management of Red-cockaded Woodpecker, II. Florida Game and Fresh Water Fish Commission, U.S. Fish and Wildlife Service.

F. Canby's Dropwort

Canby's dropwort (*Oxypolis canbyi*) is a rare plant found in a variety of wetland habitats, including wet pine savannas, shallow pineland ponds, and sloughs of the southeastern U.S. It was placed on the Federal Register of endangered species in 1986, and is officially listed as a threatened species of national concern by the State of South Carolina (USFWS 1986). Because suitable habitat for this species could potentially occur at some of the upland candidate dredged material disposal sites (e.g., Rodent Island), Canby's dropwort is an appropriate rare and endangered species to use for defining and evaluating the potential impact of alternative dredged material disposal sites.

Distribution and Ecology:

Canby's dropwort prefers habitats that are rarely inundated to depths greater than 12 inches and are saturated with water year-round (Bowling 1986, Rayner et al. 1987). The soils in the preferred habitat of Canby's dropwort should be poorly drained sandy loams or acidic peat-mucks with medium to high organic content which are underlain by clay layers (Aulbach-Smith 1985). The largest and most vigorous populations of Canby's dropwort occur in open bays or ponds that are wet for most of the year (USFWS 1990). Canby's dropwort can tolerate droughts if the water table remains near the soil surface (~ 35 cm). However, when the water table drops below 150 cm, high mortality occurs to Canby's Dropwort (Rayner 1988, Rayner et al. 1987, Boyer 1988). Ditching and draining of wetlands in a manner that lowers the water level in the wetland generally adversely affect populations of Canby's dropwort (Ormes et al. 1985, USFWS 1986). Extreme floods also adversely impact Canby's dropwort. Although there is no documentation of Canby's dropwort in the study area, the soils in the vicinity of Rodent Island has characteristics suitable for supporting populations of this plant (Long 1980). Most existing populations of Canby's dropwort are maintained through asexual reproduction by means of rhizomes (Aulbach-Smith 1985, USFWS 1990), but this plant also produces seeds. Mechanisms of seed disposal are not known, nor is the importance of vegetative versus sexual reproduction (USFWS 1990). At this time, there are not data that describe how Canby's dropwort colonizes new wetland systems.

Potential Impacts of Dredge Material Disposal:

The most serious threat to Canby's dropwort resulting from construction and operation of dredged material disposal sites in Charleston Harbor is the conversion of suitable freshwater wetland habitats into dredge material disposal sites. In addition, creation and operation of dredged material disposal sites that may alter hydroperiod in adjacent wetlands adversely affecting this rare plant.

References:

Audubon, J.J. 1839. Ornithological biography, Vol. 5. Edinburgh.

Aulbach-Smith, C. 1985. Element stewardship abstract for *Oxypolis canbyi*. South Carolina Office of The Nature Conservancy, Columbia, SC. 6 pp.

Bowling, S. 1986. The status of Canby's dropwort (*Oxypolis canbyi*) in Georgia. Report submitted to the Eastern Heritage Task Force, The Nature Conservancy, Boston, MA. 11 pp.

Boyer, M. 1988. Monitoring *Oxypolis canbyi* in Big Cypress Meadow (McIntosh Bay), Scotland County, North Carolina, 1986-1988. Unpublished report, North Carolina Plant Conservation Program, Raleigh, NC. 16 pp.

Long, B.M. 1980. Soil survey of Berkeley County, South Carolina. United States Department of Agriculture, Soil Conservation Service and Forest Service.

Ormes, M., L. Morse, and M. Barnett. 1985. TNC element global ranking form for *Oxypolis canbyi*. Southearstern Regional Office of the The Nature Conservancy, Chapel Hill, North Carolina.

Rayner, D., J. Nelson, and S. Hutto. 1987. Canby's dropwort (*Oxypolis canbyi*) - results of 1986 Monitoring Program. Bulletin of the South Carolina Academy of Science (Columbia) 47: 89-90.

Rayner, D. 1988. Colleton Cowbane Heritage Preserve Management Plan. South Carolina Wildlife and Marine Resources Department, Wildlife and Freshwater Fisheries Administration, Nongame and Heritage Trust Section, Columbia. 21 pp.

U.S. Fish and Wildlife Service. 1986. Endangered and threatened wildlife and plants; determination of *Oxypolis canbyi* (Canby's dropwort) to be an endangered species. Federal Register 51(37): 6690-6693.

U.S. Fish and Wildlife Service. 1990. Canby's dropwort recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

G. Oysters

The American, or eastern oyster (*Crassostrea virginica*) is widely distributed throughout the eastern U.S. including the Charleston Harbor and is harvested commercially and recreationally for human consumption. In addition, oysters have important roles in estuarine material and energy cycles (Dame and Patton 1981; Dame et al. 1984, Ulanowicz and Tuttle 1992). Oyster shells, and the reefs they form, provide habitat for abundant populations of worms and crustaceans (Manzi et al. 1985; Burrell 1986) that are preferred prey of many commercially and recreationally important fishes (e.g., red drum, spotted seatrout). Oyster reefs also provide cover and foraging habitat for crabs and shrimp (Burrell 1986). During low tide, oyster reefs are the preferred foraging habitat for numerous species of wading birds (e.g., oystercatchers, willets, and turnstones). Because of their key roles in estuarine material cycles and food web dynamics, oysters are often considered a "keystone" species for estuaries.

<u>Distribution and Ecology</u>:

Oysters are adapted to live within a wide range of environmental conditions and can tolerate extreme short-term fluctuations in conditions such as temperature, salinity and dissolved oxygen by closing their shells and maintaining metabolic activity at basal levels (Galtsoff 1964; Loosanoff 1965). Oysters inhabit salinities from full-strength seawater (~35 ppt) to brackish water areas as low as 8-10 ppt. In southeastern estuaries (e.g., Charleston Harbor), oysters live in both subtidal and intertidal habitats, although greatest biomass and densities occur intertidally (Bahr 1974; Dame 1979; Burrell 1986). In Charleston Harbor, extensive beds of subtidal oysters occur in the Wando River and several of its tributaries (Gracy and Keith 1972). Subtidal oyster populations are mainly confined to lower salinity habitats (Manzi et al. 1977). Reduced abundance of oyster predators at lower salinities, including drills (*Urosalpinx cinerea, Eupleura caudata*) and boring sponges (*Clione cellata*), has been implicated as factors contributing to the presence of subtidal oyster beds.

Burrell et al. (1984) reported that oysters spawn intermittently from May to November, with a peak in mid-summer for subtidal oysters and two narrower peaks in early summer and fall for intertidal oysters. Oyster larvae are planktonic and remain in the water column for 10 to 21 days depending on temperature, salinity, and the availability of suitable food. The larvae settle to the bottom and attach to hard substrates at a size of about 3 mm. Oyster larvae, or spat as the newly attached oysters are known, show a marked preference for settling on oyster shell compared to other hard substrates (Galtsoff 1964; Loosanoff 1965; Burrell 1986). In the Charleston area, spatfall is heaviest subtidally, but survival is best intertidally. Growth is relatively rapid (1-4 mm/month) and continuous throughout the year (Manzi et al. 1977; Burrell et al. 1981).

Potential Impact of Dredged Material Disposal:

Although oysters can tolerate extreme environmental fluctuations, they are sensitive to changes in conditions associated with creation and operation of dredged material disposal sites, including increases in turbidity, high sedimentation, and chemical contamination. Excessive turbidity clogs the filtering apparatus of oysters, reducing growth, and may ultimately cause mortality (Loosanoff 1962; Galtsoff 1964). In addition, shellfish such as oysters bioaccumulate chemical and microbial contaminants in their tissues making them less desireable for human consumption (Kopfler and Mayer 1969; Huggett et al. 1973). High concentrations of contaminants in oyster tissues also has ecological implications. The National Shellfish Sanitation Program samples oysters as sentinels of microbial contamination, and the National Status and Trends Monitoring Program (NOAA 1989) use oysters as indicators of the degree and extent of chemical contamination in estuarine waters.

References:

Bahr, L.M. 1974. Aspects of the structure and function of the intertidal oyster reef community in Georgia. Ph.D. Dissertation. University of Georgia, Athens.

Burrell, V.G. Jr., J.J. Manzi, and W.Z. Carson. 1981. Growth and mortality of two types of seed oysters from the Wando River, South Carolina. J. Shellfish Res. 1(1): 1-7.

Burrell, V.G. Jr., M.Y. Bobo, and J.J. Manzi. 1984. A comparison of seasonal incidence and intensity of *Perkinsus marinus* between subtidal and intertidal oyster populations in South Carolina. J. World Maricul. Soc. 55: 301-309.

Burrell, V.G. Jr. 1986. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) - American Oyster. U.S. Fish. Wildl. Serv. Biol. Rep. 82(11.57). U.S. Army Corps of Engineers TR-EL-82-4. 17pp.

Dame, R.F. 1979. The abundance, diversity and biomass of macrobenthos on North Inlet, South Carolina, Intertidal oyster reefs. Proc. Natl. Shellfish. Assoc. 69: 6-10.

Dame, R.F. and B.C. Patton. 1981. Analysis of energy flows in an intertidal oyster reef. Mar. Ecol. Prog. Ser. 5: 115-124.

Dame, R.F., R.G. Zingmark, and E. Haskin. 1984. Oyster reefs as processors of estuarine materials. J. Exper. Mar. Ecol. 83: 239-247.

Galtsoff, P.S. 1964. The American oyster, *Crassostrea virginica* Gmelin. U.S. Fish. Wildl. Serv. Bull. 64 480pp.

Gracy, R.C. and W.J. Keith. 1972. Survey of the South Carolina oyster fishery. Tech. Rep. No. 3. South Carolina Marine Resources Department.

Huggett, R.J., M.E. Bender, and H.D. Sloane. 1973. Utilizing metal concentration relationships in the eastern oyster (*Crassostrea virginica*) to detect heavy metal pollution.

Kopfler, F.C. and J. Mayer. 1969. Studies on trace metals in shellfish. Proc. Gulf and So. Atl. Shellfish Sanitation Research Conference, March 1967, Gulf Coast Marine Health Science Laboratory, Dauphin Island, Alabama.

Loosanoff, V.L. 1962. Effects of turbidity on some larval and adult bivalves. Proc. Gulf Caribb. Fish. Inst. 14: 80-95.

Loosanoff, V.L. 1965. The American or Eastern Oyster. U.S. Fish. Wildl. Ser. Bureau of Comm. Fish. circular 205. 36pp.

Manzi, J.J., V.G. Burrell, Jr., K.J. Klemanowica, N.H. Hadley, and J.A. Collier. 1985. Impacts of a mechanical harvester in intertidal oyster communities in South Carolina. Final Report. Coastal Energy Impact Program, Office of the Governor, Columbia, SC. 31pp.

Manzi, J.J., V.G. Burrell, Jr., and W.Z. Carson. 1977. A comparison of growth and survival of subtidal *Crassostrea virginica* (Gmelin) in South Carolina salt marsh impoundments. Aquaculture 12: 293-310.

NOAA. 1989. A summary of data on tissue contamination from the first three years (1986-1988) of the mussel watch project. NOAA Technical Memorandum NOA OMA 49.

Ulanowicz, R.E. and J.H. Tuttle. 1992. The trophic consequences of oyster stock rehabilitation in Chesapeake Bay. Estuaries 15(3): 298-306.

H. Freshwater Marsh Plants

Freshwater wetland plants have functional roles in controlling flooding and erosion of adjoining lands. They also are important in maintaining the water quality of streams, rivers, lakes, estuaries, and coastal waters and are preferred habitat for many types of wildlife. These plants, however, respond to changes in hydrology which may be associated with construction and operation of dredged material disposal facilities with large changes in abundance and distribution. Freshwater wetland plants are therefore an appropriate selection as a Representative Important Biota for evaluating alternative dredged material disposal sites on the Charleston Harbor ecosystem.

Economic Value:

Some of the larger trees that occur in freshwater wetlands are harvested as timber (e.g., cypress). Freshwater wetland plants also provide habitat for migratory waterfowl and other wildlife that contribute to the state's hunting industry (McGilvrey 1966, Kerwin and Webb 1972, Sandifer et al. 1980).

Distribution and Ecology:

The species composition and abundance of freshwater wetland plants is controlled by the duration of flooding (hydroperiod) and soil characteristics. These major hydroperiod classes that occur in the Charleston region are: intermittently-flooded, temporarily-flooded, and seasonally-flooded freshwater marshes. Intermittently-flooded marshes are inundated for variable amounts of time throughout the year. Temporarily-flooded freshwater wetlands are inundated briefly during the spring and summer growing season. Seasonally-flooded freshwater wetlands are inundated for most of the spring and summer growing season. Intermittently-flooded marshes, commonly called depression meadows, are dominated by smartweeds (*Polygonum* spp.), milkworts (*Polygala* spp.), butterworts (*Pinquicula* spp.), water primroses (*Ludwigia* spp.), meadow beauties (*Rhexia* spp.), and yellow-eyed grasses (*Xyris* spp.). Temporarily-flooded marshes are dominated by hydrophylic species of bulrushes (*Scirpus* spp.), sedges (*Carex* spp.), nutrushes (*Scleria* spp.), spikerushes (*Eleocharis* spp.), and umbrella-sedges (*Cyperus* spp.). Grasses (*Panicum* spp.) and blue flags (*Iris* spp.) are also frequently found in temporarily-flooded marshes (Nelson 1986). The dominant vegetation characteristic of seasonally-flooded marshes include arrowweeds (*Sagittaria* spp.), pickerelweeds (*Pontedaris* spp.), mosquito fern (*Azolla* spp.), duckweeds (*Lemna* spp., *Spirodela* spp., *Wolffia* spp.), water lilies (*Nymphaea* spp.), and floating hearts (*Nymphoides* spp.). Many of the above freshwater wetland plants are an important food item for many birds and other wildlife species (Bellrose and Trudeau 1988, Sandifer et al. 1980). Several endangered and threatened species of wildlife are intimately associated with freshwater wetlands. For example, Bachman's warbler, a rare summer resident (perhaps now extinct, [Laurie, pers. comm.]) of the South Carolina low country, appears to be dependent upon freshwater wetlands (Shuler 1977). These wetlands also provide refuges and nursery habitat for more abundant wildlife including deer, bobcat, fox, beaver, and many species of waterfowl and wading birds (Schroeder 1985). Freshwater wetland plants also serve as sinks for nutrients and trap sediments helping maintain the quality of the nations water bodies.

Potential impacts of dredge material disposal:

Construction and operation of dredged material disposal facilities in low lying areas will result in direct losses of freshwater wetland habitat by converting them to disposal areas. Because of altered hydroperiod, environmental conditions in disposal areas do not favor re-establishment of freshwater wetland plants. In addition, creation and operations of disposal facilities may alter hydroperiod in adjacent lands adversely affecting freshwater wetland plants. Large scale decreases in the abundance of freshwater marsh plants may adversely impact regional water quality.

References:

Bellrose, F.C. and N.M. Trudeau. 1988. Wetlands and their relationship to migrating and winter populations of waterfowl. Pg. 183-194 in Hood, D.D., W.H. McKee Jr., H.K. Smith, J. Gregory, V.G. Burrell Jr., M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Mathews, and T.H. Shear (eds.). The ecology and management of wetlands, Vol. 1: ecology of wetlands. Timber Press, Portland, Oregon. (MRRI QH541.5M3E29).

Kerwin, J.A. and L.G. Webb. 1972. Foods of ducks wintering in coastal South Carolina, 1965-1967. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 25: 223-245.

Laurie, P.B. Personal Communication. Office of Conservation, Education, and Communication, S.C. Wildlife and Marine Resources Department, P.O. Box 12559, Charleston, S.C. 29412.

McGilvrey, F.B. 1966. Fall food habits of ducks near Santee Refuge, South Carolina. Journal of Wildlife Mangement 30(3): 577-580.

Nelson, J.B. 1986. The natural communities of South Carolina. Division of Wildlife and Freshwater Fisheries, S.C. Wildl. & Mar. Resour. Dept., Columbia, S.C. 48pp.

Sandifer, P.A., J.V. Miglarese, D.R. Calder, J.J. Manzi, and L.A. Barclay. 1980. Ecological characterization of the sea island coastal region of South Carolina and Georgia, Vol. III: Biological features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/42. 620pp.

Schroeder, R.L. 1985. Habitat suitability index models: eastern wild turkey. U.S. Fish and Wildlife Services. Biological Report 82(10.106). 36pp.

Shuler, J. 1977. Bachman's warbler habitat. Chat 41(2): 19-20.

I. White Shrimp:

The white shrimp (*Penaeus setiferus*) is included as a Representative Important Biota on the basis of its economic value as a commercially and recreationally harvested shellfish. However, this species also has an important role in material and energy cycles within South Carolina estuaries.

Economic Value:

Commercial shrimp landings in South Carolina totaled over 3 million pounds in 1990, and almost 6 million pounds in 1991 (SCWMRD landings data), making shrimp the state's most valuable fishery. Of these totals, 70-75% of the catch was white shrimp. In addition, recreational "shrimpers" landed 2.75 million pounds of shrimp in the fall of 1990 with an estimated economic value of >$7 million. Most of the shrimp taken by recreational shrimpers are white shrimp.

Distribution and Ecology:

White shrimp are abundant in nearshore and estuarine waters throughout the Southeast. In nearshore waters between Cape Canaveral and Cape Fear, they are the most abundant decapod in trawl surveys (Wenner and Wenner 1989). White shrimp are also abundant in estuarine habitats occurring over a wide range of sediment types, salinity zones, depth strata, and wetland types (Bishop et al. 1980, Stender and Martore 1990). This species is a preferred food resource for numerous species of recreationally and commercially important finfish and plays an important role within the estuarine and coastal habitats (Muncy 1984).

White shrimp have a complex life cycle involving 11 larval stages (Muncy 1984).

Spawning occurs in the nearshore oceanic waters, and larval stages are transported shoreward by currents. White shrimp enter estuaries as postlarvae at a size of about 7 mm during late spring and early summer and disperse into tidal creeks and estuarine headwaters to begin a bottom-dwelling existence (Bearden 1961, Williams 1965, Muncy 1984). As they grow, a steady movement toward higher salinity environments culminates in emigration from the estuary at a size of about 100 mm (SAFMC 1981). Declines in water temperature that occur in fall hasten the off-shore movement (Lindner and Anderson 1956). Once offshore, shrimp movements parallel the coastline. They generally move southward in winter and northward in early spring (Lindner and Anderson 1956).

Postlarvae consume decaying organic matter, mainly marsh grasses, and microorganisms in the sediments (Odum 1971, Carr and Adams 1973). Adults and juveniles are omnivorous. Growth of white shrimp is rapid (18-30 mm/month) but variable depending on environmental conditions including temperature and salinity, and on population density (SAFMC 1981). Shrimp abundance in any given year is determined primarily by environmental factors mainly winter temperature and spring rainfall (Muncy 1984, SAFMC 1981). Juvenile shrimp are most abundant in lower salinity habitats at the marsh/tidal creek interface.

Potential Impacts of Dredge Material Disposal:

Juvenile white shrimp are dependent upon salt marshes and associated tidal creeks as nursery habitat. Destruction or degradation of this habitat to create dredge material disposal sites would adversely affect productivity of the shrimp fishery. Increased siltation and/or chemical contamination of sediments in salt marshes or tidal creeks may also adversely impact juvenile shrimp and propagate contaminants through the estuarine food chain. Offshore activities associated with dredged material disposal may adversely affect egg and/or larval development or interfere with movement or migration of white shrimp at some candidate sites (i.e., Folly Beach berm creation and large-scale dumping in the ODMDS area).

References:

Bearden, C.M. 1961. Notes on postlarvae of commercial shrimp *Penaeus* in South Carolina. Contributions from Bears Bluff Laboratories No. 33.

Bishop, J.M., J.G. Gosselink, and J.H. Stone. 1980. Oxygen consumption and hemolymph osmolality of brown shrimp, *Penaeus aztecus*. Fish. Bull., U.S. 78(3): 748-757.

Carr, W.E. and C.A. Adams. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. Trans. Am. Fish. Soc. 102(3): 511-540.

Lindner, M.J. and W.W. Anderson. 1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus*. U.S. Fish. Wildl. Serv. Bull. 56: 554-645.

Muncy, R.J. 1984. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates. South Atlantic -- White Shrimp. U.S. Fish. Wildl. Serv. FWS/OBS-82/11.27. U.S. Army Corps of Engineers. TR-EL-82-4. 19pp.

Odum, W.E. 1971. Pathways of energy flowing a south Florida estuary. University of Miami Ph.D. Dissertation. Dissert. Abst. Univ. Mich. 70-18, 156: 1898B.

South Atlantic Fishery Management Council. 1981. Profile of the penaeid shrimp fishery in the South Atlantic. Publ. of the Natl. Mar. Fish. Serv., NOAA. 306pp.

SCWMRD Landings Data. Office of Fisheries Management. South Carolina Wildlife and Marine Resources Department, PO Box 12559, Charleston, SC, 29422.

Stender, B.W. and R.M. Martore. 1990. Chapter VIII. Finfish and invertebrate communities In: A physical characterization of the Charleston Harbor estuarine system, R.F. Van Dolah, P.H. Wendt, and E.L. Wenner (eds.). Final Report to S.C. Coastal Council, Grant #NA87AA-D-CA068: 241-288.

Wenner, E.L. and C.A. Wenner. 1989. Seasonal composition and abundance of decapod crustaceans from coastal habitats, southeastern United States. Fish. Bull., U.S. 87(1): 155-176.

Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. 65(1): i-xi + 298pp.

J. Black Sea Bass

The black sea bass (*Centropristis striata*) is included as a Representative Important Biota because they are: (1) an important recreational and commercial species of nearshore coastal habitats (Low and Waltz 1991), and (2) a numerically dominant species inhabiting shallow water live bottom habitats (Powles and Barans 1980).

<u>**Economic Value:**</u>

In 1988, recreational anglers in South Carolina landed an estimated 751,000 black sea bass. This was almost six times the combined total of all other offshore recreational bottomfish landings (Waltz et al. 1990). Black sea bass along the South Carolina coast are also harvested commercially; in recent years, commercial catches have averaged about 15 percent of recreational landings (Low 1982).

Distribution and Ecology:

Black sea bass are found along the Atlantic coast from Cape Cod south to Cape Canaveral and occasionally as far south as the Florida Keys (Fischer, 1978). They typically occur in depths ranging from 10 to 120 m but are most abundant in the 20 to 60 m range (Struhsaker 1969, Sedberry and Van Dolah 1984, Mercer 1989). The age and size of black sea bass increases with increasing water depth (Cupka et al. 1973, Waltz et al. 1979, Low and Waltz 1991). In the Charleston area, juvenile black sea bass inhabit high salinity shell bottoms of estuaries (Cupka et al. 1973). Juveniles and young-of-the-year are also found in the proximity of inshore jetties and piers (Mercer 1989).

North of Cape Hatteras, black sea bass exhibit seasonal movements: inshore and northward in spring, offshore and southward in fall (Mercer 1989). In the South Atlantic Bight, black sea bass movements are mainly changes in distributional patterns that accompany growth and increased age (Cupka et al. 1973, Low and Waltz 1991).

Black sea bass are protogynous hermaphrodites. That is, most individuals mature and function first as females, and later undergo a sexual change to become functional males (Wenner et al. 1986, Mercer 1989). Although specific spawning sites are unknown, spawning clearly occurs in offshore environments (Mercer 1978, Wenner et al. 1986, Mercer 1989). The major spawning period is from January through April (Cupka et al. 1973, Wenner et al. 1986). A minor spawning peak occurs from September through October. Fecundity is directly related to size and age, with older fish producing up to 50 times more eggs than smaller fish.

Black sea bass eggs are pelagic and hatch in 3-5 days depending on temperature (Wilson 1891, Hoff 1970). The pelagic phase of the larvae lasts for several weeks, ending at a size of about 13 mm, when the juveniles become demersal (Kendall 1972). An unknown percentage of the black sea bass larvae enter coastal estuaries, and use environments containing oyster shell as nursery habitat (Cupka et al. 1973, Low 1982, Mercer 1989). Juveniles also use shallow live bottom and algae patches in offshore areas as nursery habitat (George Sedberry pers. comm.).

Black sea bass reach the legally harvestable size of 204 mm, or about 124 gm, within 3 years (Wenner et al. 1986). Females comprise over 50% of the population up to about 200 mm (age 4). After age 4, males dominate black sea bass populations (Wenner et al. 1986). Females mature rapidly with over 90% of age 2 and 99% of age 3 females capable of reproduction. The current state record black sea bass was caught near Charleston in 1975. It weighed 3,515 grams and had an estimated total length of 683 mm. Up to 10 age groups have been identified for black sea bass populations in the South Atlantic Bight (Waltz et al. 1979, Wenner et al. 1986, Mercer 1989). Fishing pressure is the major factor controlling mortality and size distributions of black sea bass populations (Wenner et al. 1986).

The black sea bass is a carnivorous predator and feeds on invertebrates and small fish associated with live bottom habitats including crustaceans, fishes, mollusks, and echinoderms (Hildebrand and Schroeder 1928, Link 1980, Mercer 1989). Adults feed mostly on larger crabs and fish, while juveniles eat mostly smaller shrimp, isopods, and amphipods (Mercer 1989). Cupka et al. (1973) reported that adults also graze on barnacles and tunicates. Black sea bass are a numerically dominant member of the fish community inhabiting shallow water live bottom and artificial reef habitats. Other associated fishes include round scad, scup, tomtate, sand perch, porgys, and wrasses.

Potential Impacts of Dredge Spoil Disposal:

Known aspects of the life history and ecology of black sea bass suggest a potential for adverse impacts from disposal of dredge material in two major areas: (1) loss and/or adverse impacts to the estuarine and nearshore nursery habitat (e.g., shell bottom and nearshore live bottom), and (2) loss and/or adverse impacts to live bottom habitat which is the primary habitat for young females. Adverse impacts include reduction in the amount and kind of cover (e.g., sponges and corals) and food (e.g., amphipods and crabs) from direct deposition of dredged material on nearshore live bottom and estuarine shell habitat, and/or resuspension and movement of newly deposited dredged material into live bottom habitats by natural hydrodynamic processes. Reductions in water quality (e.g., increased turbidity) may also adversely impact the biota (i.e., reef forming sponges and corals) upon which black sea bass depend for cover and food.

References:

Cupka, D.M., R.K. Dias, and J. Tucker. 1973. Biology of the Black Sea Bass from South Carolina waters. S.C. Wildlife and marine Resources Department (Unpublished Manuscript). 93pp.

Fischer, W. (ed.). 1978. FAO species identification sheets for fishery purposes. Western Central Atlantic. FAO, Rome. Vol. 4.

Hildebrand, S.F. and W.C. Schroeder. 1928. Fishes of Chesapeake Bay. U.S. Bur. Fish. Bull. 43. 366pp.

Hoff, F.H. Jr. 1970. Artificial spawning of the black sea bass, *Centropristes striatus melanus* Ginsburg, aided by chorionic gonadotrophic hormones. Fla. Dep. Nat. Resour. Mar. Res. Lab. Spec. Sci. Rep. No. 25. 17pp.

Kendall, A.W. Jr. 1972. Description of black sea bass, *Centropristis striata* (Linneaus), larvae and their occurrences north of Cape Lookout, North Carolina, in 1966. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 70(4): 1243-1260.

Link, G.W. Jr. 1980. Age, growth, reproduction, feeding and ecological observations on three species of *Centropristis (Pisces: Serannidae)* in North Carolina waters. Ph.D. thesis. University of North Carolina, Chapel Hill. 277pp.

Low, R.A. 1982. The South Carolina fishery for Black Sea Bass *Centropristis striata*, 1977-1981. South Carolina Marine Resources Center Technical Report No. 53.

Low, R.A. and C.W. Waltz. 1988. South Carolina marine recreational fishery statistics survey 1987. South Carolina Marine Resources Center Technical Report No. 68.

Low, R.A. and C.W. Waltz. 1991. Seasonal utilization and movement of Black Sea Bass on a South Carolina artificial reef. North American Journal of Fisheries Management 11: 131-138.

Mercer, L.P. 1978. The reproductive biology and population dynamics of black sea bass, *Centropristis striata*. Ph.D. Thesis, College of William and Mary, Williamsburg VA. 196pp.

Mercer, L.P. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) -- Black Sea Bass. U.S. Fish. Wildl. Serv. Biol. Rep. 82(11.99). U.S. Army Corps of Engineers, TR-EL-82-4. 16pp.

Powles, H. and C.A. Barans. 1980. Groundfish monitoring in sponge coral areas off the southeastern United States. U.S. Natl. Mar. Fish. Serv. Mar. Fish. Rev. 42(5): 21-35.

Sedberry, G.R. and R.F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the U.S.A. Enviorn. Biol. Fish. 11(4): 241-258.

Sedberry, G.R. Pers. Comm. South Carolina Marine Resources Research Inst., PO Box 12559, Charleston, SC 29422.

Struhsaker, P. 1969. Demersal fish resources: Composition, distribution and commercial potential of the continental shelf stocks off the southeastern United States. U.S. Fish. Wildl. Serv. Fish. Ind. Res. 4(7): 261-300.

Waltz, C.W., W.A. Roumillat, and P.K. Ashe. 1979. Distribution, age structure and sex composition of the black sea bass, *Centropristis striata*, sampled along the southeastern coast of the United States. S.C. Marine Resources Center Tech. Rept. No. 43. 18pp.

Waltz, C.W., D.B. Stone III, U. West, E. Hens, and R.A. Low. 1990. South Carolina marine recreational fish and shellfish surveys, 1988. South Carolina Wildlife and Marine Resources Dept., Marine Resources Division, Office of Fisheries Management, Technical Rept. No. 75.

Wenner, C.A., J.C. McGovern, R. Martore, H.R. Beatty, and W.A. Roumillat. 1986. Ichthyofauna. In: M.R. DeVoe and D.S. Baughman (eds.), South Carolina Wetland Impoundments: Ecological Characterization, Management, Status and Use. Vol. II, Technical Synthesis, S.C. Grant. 415-523.

Wilson, H.V. 1891. The embryology of the sea bass *Serranus atrarius*. U.S. Fish. Comm. Bull. for 1889. 9: 209-277.

K. The Blue Crab

The blue crab (*Callinectes sapidus*) is abundant and widely distributed throughout the Charleston Harbor estuarine system and the adjacent offshore areas (Wenner and Wenner 1988, Mense and Wenner 1989, Archambault et al. 1990). It supports substantial commercial and recreational fisheries (Low et al. 1987), and plays an important part in material and energy cycles of estuaries (Van Den Avyle 1984). For these reasons, it is considered an appropriate Representative Important Biota for evaluating the effects of construction and operation of dredged material disposal sites on estuarine environments.

Economic Value:

Among the commercial fisheries of South Carolina, blue crab ranks second to white shrimp in dollar value and pounds landed (Eldridge and Waltz 1977). Over the last five years, total landings of blue crab have averaged about 6 million pounds with an average ex-vessel value of $2.6 million (SCWMRD landings data). An extensive recreational fishery for blue crabs also exists, the dollar value of which has not been estimated (Eldridge and Waltz 1977). About 24 percent of shore based recreational fishermen reported crabbing as their exclusive activity, while 27% of the boaters surveyed reported some crabbing activities (Low et al. 1987). Although recreational crabbers are allowed the unlicensed use of up to two crab pots (per head of household), most recreational crabbing is by means of bait and dipnet, and takes place on and around public and private docks, piers, and bridges (David Whitaker, pers. comm.).

Distribution and Ecology:

Blue crabs are broadly distributed along the Atlantic and Gulf coasts. Their distribution within estuaries is dependant on the life stage and sex of the individuals and on the time of year. Male crabs are most abundant in South Carolina tidal creeks (Lunz 1951). Females are more abundant in nearshore waters (Eldridge and Waltz 1977). Blue crabs mate in low to moderate salinity waters (Williams 1965, Tagatz 1968). After mating, the female begins a migration toward higher salinity where she will produce one or more egg masses ("sponges") over a one to two year period (Van Engle 1958, Williams 1984). The fertilized eggs are extruded by the female,and incubate from 12 to 17 days while attached to the abdominal appendages (Churchill 1921, Sandoz and Rogers 1944). Ovigerous females are found in Charleston Harbor as early as March 14 and as late as November 24; the peak in reproduction, however, occurs between April and August (Archambault et al. 1990).

Like other crustaceans, blue crabs develop through a series of larval, juvenile, and adult stages, often undergoing dramatic changes in appearance and behavior. The first larval stages are called zoea, and, depending on temperature and salinity, may last from 31 to 49 days (Van Den Avyle 1984). Zoea are planktonic, and occur mainly in surface waters (Darnell 1959, Tagatz 1968, Low et al. 1987). Larvae which hatched inshore are transported by surface currents into offshore waters where they continue their development (Mense and Wenner 1989). The final molt of the zoea results in a crablike form known as a megalops, which lasts from 6 to 20 days (Van Den Avyle 1984). The free swimming megalopae orient toward the bottom and are transported into estuaries by currents where they metamorphose into juvenile crabs (Tagatz 1968, Mense and Wenner 1989). Megalopae are more abundant in higher salinity areas of estuaries while juveniles are more abundant in brackish water habitats suggesting that after metamorphosis, juvenile crabs migrate to lower salinity waters (Mense and Wenner 1989). Peak abundance of megalopae occurs during March and October. Peak juvenile abundance occurs in January and September.

Growth takes place in conjunction with molting and is influenced by temperature, availability of food, and growth stage (Milliken and Williams 1984). In South Carolina, highest growth occurs from March through October (Low et al. 1987). Male crabs in Charleston Harbor reach maturity 11 to 12 months after hatching, and females mature after 15-20 months (Archambault et al. 1990). Adult blue crabs rarely move from one estuarine system to another (Van Den Avyle 1984). Upon reaching maturity, males tend to remain in lower salinity areas while females move to higher salinity waters after mating (Williams 1965, Van Den Avyle 1984). In winter, crabs move to deeper, warmer water, and return to creek and marsh habitats in the spring (Livingston 1976).

The various stages in the life cycle of the blue crab afford it a variety of functions within the ecosystem. The larvae are planktivorous (Darnell 1959, Tagatz 1968). Megalopae are omnivorous, and adults function as scavengers, carnivores, detritivores, and omnivores (Darnell 1959, Adkins 1972, Van Den Avyle 1984). Dominant food items include: dead and live fish, crabs, organic debris, shrimp, mollusks, and plant parts. Adults are a major predator of benthic infauna, particularly clams (Virnstein 1977, Darnell 1958). Throughout their life cycle, blue crabs are preyed upon by a wide range of organisms. Adkins (1972) reported blue crab eggs to be a favorite food of many fishes. Larval blue crabs are consumed by fishes, jellyfish and comb jellies, and mollusks (Van Engle 1958). Juvenile blue crabs are important prey for inshore fish species, such as red drum and sheepshead (Van Den Avyle 1984). Adults are consumed by a variety of mammals and birds and are an important prey item for large fish, especially sharks and rays (Castro 1983).

Potential Impacts of Dredge Material Disposal:

The most serious threat from dredged material disposal to the blue crab population is the potential for destruction and/or degradation of salt marsh which is the nursery grounds for juveniles. Many authors (Weinstein, 1979, Low et al. 1987, Mense and Wenner 1989, Orth and Montfrans 1990) have stressed the importance of a stable salt marsh habitat to the sustainability of blue crab populations.

References:

Adkins, G. 1972. A study of the blue crab fishery in Louisiana. La. Wildl. Fish. Comm., Oyster, Water Blooms and Seafood Div. Tech. Bull. No. 3. Baton Rouge, LA. 57pp.

Archambault, J.A., E.L. Wenner, and J.D. Whitaker. 1990. Life history and abundance of blue crab, *Callinectes sapidus* Rathbun, at Charleston Harbor, South Carolina. Bull. Mar. Sci., 46(1): 145-158.

Castro, J.I. 1983. The sharks of North American waters. Texas A & M Univ. Press. 180 pp.

Churchill, E.P. Jr. 1921. Life history of the blue crab. Bull. Bur. Fish. 36: 91-128.

Darnell, R.M. 1958. Food habits of fishes and larger invertebrates in Lake Ponchartrain, Louisiana, an estuarine community. Publ. Inst. Mar. Sci. Univ. Tex. 5: 353-416.

Darnell, R.M. 1959. Studies of the blue crab, *Callinectes sapidus* Rathbun, in Louisiana waters. Trans. Am. Fish. Soc. 88: 294-304.

Eldridge, P.J. and C.W. Waltz. 1977. Observations on the commercial fishery for blue crabs, *Callinectes sapidus*, in estuaries in the southern half of South Carolina. South Carolina Marine Resources Center Technical Rept. No. 21.

Livingston, R.J. 1976. Diurnal and seasonal fluctuations of organisms in a north Florida estuary. Estuarine Coastal Mar. Sci. 4: 373-400.

Low, R.A., R. Rhodes, E.R. Hens, D. Theiling, E.L. Wenner, and J.D. Whitaker. 1987. A profile of the blue crab and its fishery in South Carolina. South Carolina Marine Resources Center Technical Rept. No. 66.

Lunz, G.R. 1951. Investigations of trawling for crabs in inshore waters of South Carolina. Report to the S.C. Board of Fisheries. Bears Bluff Lab, Wadmalaw Is., S.C. 12pp.

Mense, D.J. and E.L. Wenner. 1989. Distribution and abundance of early life history stages of the blue crab, *Callinectes sapidus*, intertidal marsh creeks near Charleston, South Carolina. Estuaries 12(3): 157-168.

Millikin, M.r. and A.B. Williams. 1984. Synopsis of biological data on the blue crab, *Callinectes sapidus* Rathbun. NOAA Tech. Rept. NMFS 1, FAO Fisheries Synopsis No. 138. 39pp.

Orth, R.J. and J. Van Montfrans. 1990. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*: a latitudinal perspective. Bull. Mar. Sci. 46(1): 126-144.

Sandoz, M. and R. Rogers. 1944. The effect of environmental factors on hatching, molting, and survival of zoea larvae of the blue crab, *Callinectes sapidus* Rathbun. Ecology 25: 216-228.

South Carolina Wildlife and Marine Resources Department. Unpublished county landings reports. Office of Fishery Management. South Carolina Wildlife and Marine Resources Department, P.O. Box 12559, Charleston, SC 29422.

Tagatz, M.E. 1968. Biology of the blue crab, *Callinectes sapidus* Rathbun, in the St. Johns River, Florida. U.S. Fish Wildl. Serv. Fish. Bull. 67: 17-33.

Van Den Avyle, M.J. 1984. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) -- Blue Crab. U.S. Fish. Wildl. Serv. FWS/OBS-82-11.19. U.S. Army Corps of Engineers, TR-EL-82-4. 16pp.

Van Engle, W.A. 1958. The blue crab and its fishery in Chesapeake Bay. Part I. Reproduction, early development, growth, and migration. Comm. Fish. Rev. 20(6): 6-17.

Virnstein, R.W. 1977. The importance of predation by crabs and fishes in benthic infauna in Chesapeake Bay. Ecology 58: 1199-1217.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fish and shellfish, Cape Fear River, North Carolina. U.S. Natl. Mar. fish. Serv. Fish. Bull. 77: 339-357.

Wenner, E.L. and C.A. Wenner. 1988. Seasonal composition and abundance of decapod and stomatopod crustaceans from coastal habitats, southeastern United States. Fish. Bull. U.S. 87(1): 155-176.

Whitaker, J.D. Pers. Comm. S.C. Wildlife and Marine Resources Dept. P.O. Box 12559, Charleston, S.C. 29422.

Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish Wildl. Serv. Fish. Bull. 65: 1-298.

Williams, A.B. 1984. Shrimp, lobsters, and crabs of the Atlantic coast of the United States, Maine to Florida. Smithson. Inst. Press. 550pp.

L. Red Drum

The red drum (*Sciaenops ocellatus*) is arguably the most sought after inshore and nearshore gamefish, and expenditures related to the recreational fishery for red drum generate significant cash flow in the coastal economy. This species is also an abundant member of the estuarine fish community in Charleston Harbor and has important roles in food web dynamics (Shealy et al. 1974, Wenner et al. 1990). Thus, red drum is an appropriate Representative Important Biota for evaluating the impacts of construction and operation of dredged material disposal operations on the Charleston Harbor ecosystem.

Economic Value:

In surveys of recreational fishermen in coastal South Carolina (Low et al. 1986, Low and Waltz 1988, Waltz et al. 1990), red drum was consistently ranked as one of the major target species and a substantial portion of South Carolina's estimated $200 million marine recreational fishing industry is associated with red drum. Estimates of the red drum recreational catch for 1987 and 1988 were 509,000 and 511,000 fish respectively (Waltz et al. 1990).

Distribution and Ecology:

The red drum ranges from Laguna Madre, Mexico to south Florida in the Gulf of

Mexico, and along the United States Atlantic coast to New York (Fischer 1978). Juvenile and sub-adult red drum occur within the estuary; adult spawning populations almost exclusively inhabit nearshore waters (Wenner et al. 1990). In South Carolina, juvenile red drum inhabit a broad variety of estuarine habitats including flooded marshes as well as tidal creeks (Wenner et al. 1990). Salinity tolerances range from 0.8 to 33.7 ppt. Temperature tolerance ranges from 9° to 30°C (Wenner et al. 1990).

Red drum spawn in nearshore waters in proximity to inlets (Mercer 1984). In South Carolina, they spawn from mid-July through September (McGovern 1986, Wenner et al. 1990). Males mature at age three; females are mature by age four (Wenner et al. 1990). Depending on their size and age, females produce 0.5 to 3.5 million eggs (Pearson 1929). The optimal environmental condition for hatching is 25°C and 30 ppt (Buckley 1984).

Shallow brackish marsh areas of the upper estuarine reaches are the primary nursery habitat for juvenile red drum in South Carolina (Cain and Dean 1976, Wenner et al. 1990). Larvae and juveniles enter these areas from August through October. Growth is temperature dependant and rapid for the first two years (Lyczkowski-Schultz et al. 1988). The average red drum grows to about 300 mm in length during the first year. The maximum size of red drum was estimated by Welsch and Breder (1924) to be no greater than 160 cm. The estimated maximum age of red drum is about 50 years (J. Ross, NCDNR in Wenner et al. 1990).

Adult red drum composing offshore populations along the Atlantic Coast move northward and inshore as water temperature rises in spring, and southward and offshore as temperatures drop in the fall (Yokel 1966). Within estuaries, juveniles move to deeper water in winter, and return to shallower areas as temperature rises in spring (Wenner et al. 1990). Juveniles generally do not move between estuaries or migrate along the coast.

Red drum are predatory fish, and their dietary preferences change as they develop and grow. Fish less than 15 mm feed exclusively on mysids and copepods (Wenner et al. 1990). Red drum in the 60-90 mm size range feed mainly on grass shrimp. Crabs (e.g., *Callinectes spp., Arenaeus cribarius, Portunus spp. Uca spp.*) and fishes (*Brevoortia tyrannus, Leiostomus xanthurus, Mugil spp.*) are the preferred prey of large adult red drum (Yokel 1966, Overstreet and Heard 1978, Wenner et al. 1990). Large red drum (430-1,020 mm SL) also feed on sand dollars and sea cucumbers (Overstreet and Heard 1978).

<u>**Potential Impacts of Dredge Material Disposal:**</u>

Red drum are an estuarine dependant species and the long term success of their populations requires adequate nursery habitat. Activities that result in the destruction or degradation of estuarine nursery habitats of red drum, mainly shallow tidal creeks and salt marshes, would have adverse effects upon their abundance. In light of the paucity of data regarding specific mating and spawning behavior of red drum, it would also be prudent to exercise caution when contemplating disposal operations in nearshore areas, especially during the mid to late summer peak spawning period.

References:

Buckley, J. 1984. Habitat suitability index models: larval and juvenile red drum. U.S. Fish. Wildl. Serv. FWS/OBS-82/10.74. 15pp.

Cain, R.L. and J.M. Dean. 1976. Annual occurrence, abundance, and diversity of fish in a South Carolina creek. Mar. Biol. (Berl.)36: 369-379.

Fischer, W. (ed.). 1978. FAO species identification sheets for fishery purposes. West central Atlantic (fishing area 31). FAO, 6 Vols. pag. var.

Holt, J.R. and C.R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum, *Sciaenops ocellata*. Fish. Bull. 79(3): 569-573.

Low, R.A., C.W. Waltz, R. Martore, and C.J. Moore. 1986. South Carolina marine recreational fishery surveys, 1985 and 1986. South Carolina Marine Resources Center Technical Rept. No. 65.

Low, R.A. and C.W. Waltz. 1988. South Carolina marine recreational fishery statistics survey 1987. South Carolina Marine Resources Center Technical Rept. No. 68.

Lyczkowski-Shultz, J., J.P. Steen, Jr., and B.H. Comyns. 1988. Early life history of red drum (*Sciaenops ocellatus*) in the North-central Gulf of Mexico. Final Report Miss.-Ma. Sea Grant Consort. Proj. No.: F/LR-12, pt.

McGovern, J.C. 1986. Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes. M.S. Thesis, College of Charleston, Charleston, South Carolina. 123pp.

Mercer, L.P. 1984. A biological and fisheries profile of red drum, *Sciaenops ocellatus*. Special Scientific Report No. 41. North Carolina DNR and Community Development, Division of Marine Fisheries, Morehead City, NC, 28577.

Overstreet, R.M. and R.W. Heard. 1978. Food of the red drum, *Sciaenops ocellata*, from Mississippi Sound. Gulf Res. Rep. 6(2): 131-139.

Pearson, J.C. 1929. Natural history and conservation of red fish and other commercial sciaenidae of the Texas coast. Bull. U.S. Bur. Fish. 44: 129-214.

Ross, J. Pers. comm. (In: Wenner, C.A. et al. 1990). North Carolina DNR and Community Development. Manteo, N.C. 27954.

Shealy, M.H., J.V. Miglarese, and E.B. Joseph. 1974. Bottom fishes of South Carolina estuaries - relative abundance, seasonal distribution, and length-frequency relationships. South Carolina Marine Resources Center Tech. Rept. No. 6. 189pp.

Waltz, C.W., D.B. Stone III, U. West, E. Hens, and R.A. Low. 1990. South Carolina marine recreational fish and shellfish fishery surveys, 1988. South Carolina Wildlife and Marine Resources Dept., Marine Resources Division, Office of Fisheries Management, Technical Report No. 75.

Welsch, W.W. and C.M. Breder. 1924. Contribution to the life history of the Scianidae of the eastern United States. Bull. U.S. Bur. fish. 39: 141-201.

Wenner, C.A., W.A. Roumillat, J.E. Moran, Jr., M.B. Maddox, L.B. Daniel III, and J.W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina, Chapter 4. Final Report for the state of South Carolina. Funded through the Federal Aid in Fish Restoration Act, Project F-37.

Yokel, B.J. 1966. A contribution to the biology and distribution of the red drum, *Sciaenops ocellata*. M.S. Thesis. U. of Miami, Coral Gables, FL. 160pp.

M. Eastern Wild Turkey

Eastern wild turkey (*Meleagris gallopayo sylvestris*) is a highly sought-after game bird known to inhabit upland habitats in the Charleston Harbor area. In addition, considerable resources have been expended restoring turkey populations and habitat in this region. This species, therefore, is an appropriate Representative Important Biota for defining and evaluating the potential impacts of alternative dredged material disposal sites on upland sites.

Distribution and Ecology:

Eastern wild turkey is tolerant of a wide range of environmental conditions (Dickson et al. 1978). The original range of the wild turkey included 39 states (covering the entire eastern U.S.) but was reduced to 20 states by 1948 (Trippensee 1948). Twenty-five years ago, wild turkeys were almost non-existent in South Carolina (Fleming 1974). As a result of increased protection and restocking efforts in suitable but unoccupied habitat, the turkey population has increased in abundance over much of its range including South Carolina (Bailey and Rinnell 1968, Webb unpublished data).

The eastern wild turkey occupies a wide range of upland habitats (Dickson et al. 1978), Bailey et al. 1981), including hardwood forests, pine forests, and scrub/shrub areas. In South Carolina, turkeys are found in mixed pine-hardwood forests with a relatively open understory (Fleming 1974). In the study area, turkeys were observed on the Parkers Island and Cainhoy Road sites. Female turkeys build their nests on the ground in scrub/shrub areas with fairly dense cover of brush, vines, deep grass, or fallen tree tops. Hens generally lay one clutch of about nine eggs (Mosby and Handley 1943). They may produce another clutch if the first clutch is lost to predators (Mosby and Handley 1943, Williams et al. 1969, Williams et al. 1976).

Eastern wild turkeys are non-migratory birds. They do, however, move extensively throughout their home range which is typically about 5,000 acres of a multi-aged, mixed pine-hardwood forest, interspersed with ample meadow and grassy openings (Holbrook 1970, Davis 1976). The exact amount of foraging habitat required by wild turkeys is dependent on the availability of food (Wheeler 1948, Lewis 1963). The adults feed principally on plants, ranging from 86 percent plant material in winter to 98 percent plant material in summer. Important food items are oak and dogwood shoots, greenbrier, blackgum shoots, grasses, and pine shoots. Insects are an important food source for young turkeys (3 to 7 days old).

Potential Impacts of Dredge Material Disposal:

The major potential impact of construction and operation of alternative dredged material disposal sites on wild turkey populations would be loss or degradation and nesting or forage habitat. Declines in wild turkey populations have been observed in areas where prime nesting or foraging habitat have been destroyed or degraded (Holbrook 1970, Everett et al. 1985).

References:

Bailey, R.W. and K.T. Rinnell. 1968. History and management of the wild turkey in West Virginia. West Virginia Department of Natural Resources, Division of Game and Fish Bulletin No. 6. 59 pp.

Bailey, R.W., J.R. Davis, J.E. Frampton, J.V. Gwynn, and J. Shugars. 1981. Habitat requirements of the wild turkey in the southeast Piedmont. Pages 14-23 in P.T. Bromley and R.L. Carlton (eds.). Wild turkey management, current problems and programs. Missouri Chapter of the Wildlife Society and University of Missouri Press, Columbia.

Davis, J.R. 1976. Management for Alabama wild turkeys. Alabama Dept. Conserv., Special Report 5, 130 pp.

Dickson, J.G., C.D. Adams, and S.H. Hanley. 1978. Response of turkey populations to habitat variables in Louisiana. Wildlife Society Bulletin 6(3): 163-166.

Everett, D.D., D.W. Speake, and W.K. Maddox. 1985. Habitat use by wild turkeys in northern Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39: 479-488.

Fleming, W.H. 1974. Study of home ranges and gobbling activities of wild turkeys during the 1973 breeding season. S. C. Wildlife and Marine Resources Department, Division of Game and Freshwater Fisheries. Project No. W-38-10.

Holbrook, H.L. 1970. Management of wild turkey habitat in southern forest types. Pages 245-252 in G.C. Sanderson and H.S. Schultz (eds.). Wild turkey management, current problems and programs. Missouri Chapter of the Wildlife Society and University of Missouri Press, Columbia.

Lewis, J.C. 1963. Observations on the winter range of wild turkeys in Michigan. Journal of Wildlife Management 27(1): 98-102.

Mosby, H.S. and C.O. Handley. 1943. The wild turkey in Virginia, its status, life history, and management. Division of Game Commission, Inland Fisheries, Richmond, Virginia.

Trippensee, R.E. 1948. Wildlife management, vol. 1..McGraw-Hill, New York. 479 pp.

Webb, L.G. (unpublished data). 1973. Annual report: statewide wildlife research project. S.C. Wildlife and Marine Resources Department, Division of Game and Freshwater Fisheries.

Wheeler, R.J., Jr. 1948. The wild turkey in Alabama. Alabama Department of Conservation, Walker Printing Co., Montgomery. 92 pp.

Williams, L.E., Jr., D.H. Austin, N.F. Eichholz, T.E. Peoples, and R.W. Phillips. 1969. A study of nesting turkeys in southern Florida. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 22: 16-30.

Williams, L.E., Jr., D.H. Austin, and T.E. Peoples. 1976. The breeding potential of the wild turkey hen. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 30: 371-376.

N. Great Blue Heron

The great blue heron (*Ardea herodias*) is the terminal link in many aquatic food chains and the condition of heron populations reflect changes originating at several different trophic levels of the ecosystem (Custer and Osborn 1977). Reproductive success of blue herons is also sensitive to chemical contamination and habitat modification. Because of these characteristics, the U.S. Fish and Wildlife Service has used wading birds (herons and related species) as biological indicators of the coastal environmental conditions since the mid-1970's (Custer and Osborn 1977). The great blue heron is therefore an appropriate Representative Important Biota for evaluating the potential impacts of construction and operation of alternative dredged material disposal sites on the Charleston Harbor ecosystem.

Distribution and Ecology:

Great blue herons range throughout North America and are permanent residents of South Carolina (Sprunt and Chamberlain 1970). They are found throughout the Charleston Harbor estuary in a variety of habitats ranging from freshwater lakes and wetlands to estuarine marshes and maritime forests (Short and Cooper 1985). Historically, herons nested on the Drum Island site, and currently, there is an active rookery adjacent to a borrow pit at the Point Hope Island site. Herons reuse colony sites year after year (Custer and Osborn 1977) although the specific location of the active nesting area will change slightly (Custer et al. 1980). Herons generally only abandon a rookery if the availability of food in the area diminishes (Custer et al. 1980).

Great blue herons mate in spring and summer (Sprunt and Chamberlain 1970) and rear their young in rookeries. The female lays one clutch (~3 eggs/clutch) during the breeding year (Sprunt and Chamberlain 1970). Rookeries are usually located in stands of tall trees near water (McCrimmon 1978, Gibbs et al. 1987, Sprunt 1954, Burleigh 1958, Gibbs 1991). A variety of other wading birds may co-occur in heron rookeries including the great egret, little blue heron, Louisiana heron, and black-crowned night heron. Adult and juvenile blue herons forage in the adjacent shallow waters, meadows, pastures, fields, ditches, and marshes for fish, insects, salamanders, crabs, lizards, snakes, and small rodents (Meyerrieck 1960, Bayer 1978). At low tides, herons also forage on exposed tidal flats, feeding on crabs and mollusks.

Potential Impacts of Dredge Material Disposal:

Habitat destruction that results in the loss of nesting and foraging habitats has been the most important factor contributing to declines in great blue heron populations in recent years (Kelsall and Simpson 1980, McCrimmon 1981). Therefore, the greatest potential impact of construction and operation of dredged material disposal sites in Charleston Harbor on great blue heron populations would be loss of foraging and/or nesting habitat.

References:

Bayer, R.D. 1978. Aspects of an Oregon estuarine great blue heron population. Wading birds. National Audubon Society Research Report 7:99-103.

Burleigh, T.D. 1958. Georgia birds. University of Oklahoma Press, Norman.

Custer, T.W. and R.G. Osborn. 1977. Wading birds as biological indicators: 1975 colony survey. U.S. Fish and Wildlife Service. Special Scientific Report-Wildlife No. 206.

Custer, T.W., R.G. Osborn, and W.F. Stout. 1980. Distribution, species abundance, and nesting-site use of Atlantic coast colonies of herons and their allies. The Auk 97: 591-600.

Gibbs, J.P. 1991. Spatial relationships between nesting colonies and foraging areas of great blue herons. The Auk 108: 764-770.

Gibbs, J.P., S. Woodward, M.L. Hunter, and A.E. Hutchinson. 1987. Determinants of great blue heron colony distribution in coastal Maine. The Auk 104: 38-47.

Kelsall, J.P. and K. Simpson. 1980. A three year study of the great blue heron in southwestern British Columbia. Proceedings of the 1979 Conference. Colonial Waterbird Group 3:69-74.

McCrimmon, D.A., Jr. 1978. Nest-site characteristics among five species of herons on the North Carolina coast. The Auk 95: 267-280.

McCrimmon, D.A. 1981. The status and distribution of the great blue heron (Ardea herodias) in New York State: results of a two year census effort. Colonial Waterbirds 4:85-90.

Meyerrieck, A.J. 1960. Comparative breeding behavior of four species of North American herons. Nuttal Ornithol. Club Publ. 2. 158 pp.

Short, H.L. and R.J. Cooper. 1985. Habitat suitability index models: Great blue heron. U.S. Fish and Wildlife Service. Biological Report 82(10.99). 23 pp.

Sprunt, A. 1954. Florida bird life. Coward-McCann, New York.

Sprunt, A., Jr. and E.B. Chamberlain. 1970. South Carolina bird life. University of South Carolina Press, Columbia.

O. River Otter

River otter (*Lutra canadensis lataxina*) is a commercial fur bearing species that is hunted for its pelt (Chabreck et al. 1982). Otters are also an aesthetically important species because many people enjoy watching them play and swim. Because they are top predators in the aquatic ecosystems, the condition of otter populations is generally thought to reflect overall ecosystem health. The river otter is therefore an appropriate Representative Important Biota for defining and evaluating the potential impacts of construction and operation of alternative dredged material disposal sites on the Charleston Harbor ecosystem.

Economic Value:

Otters are fur bearing animals that are harvested for their pelts, and during the 1976-1977 trapping season in Louisiana, 11,900 animals having a value of $535,000 were captured and sold for their pelts (Chabreck et al. 1982). The value of the river otter in South Carolina is negligible. The greatest value of river otters is, however, as indicators of ecosystem health and for the aesthetic pleasure they provide the environmentally aware public.

Distribution and Ecology:

River otters are well established throughout South Carolina but are most abundant in the coastal marshes and blackwater swamps (Baker and Carmichael 1989). High abundances of river otter in coastal marshes have generally been attributed to the abundance of cover and food characteristic of these habitats. Otters mate in late winter and early spring (McDaniel 1963, Baker and Carmichael 1989), and the young, from 1 to 5 per litter, are born in early spring of the next year (Wilson 1959). The young stay with the mother for about a year and probably disperse just before the next litter is born (Baker and Carmichael 1989). River otters are seldom found far from an aquatic environment (Lowery 1974). They typically build nests in protected places near the water, such as in old banks, under a stump, in hollow trees, or in thick cane patches. Otters forage in saline and freshwater environments, feeding on fish, crayfish, crabs, mollusks, turtles, and waterfowl. Fish is their preferred food (McDaniel 1963, Wilson 1954, Lauhachinda and Hill 1977, Chabreck et al. 1982, Baker and Carmichael 1989).

River otters may cover 50 to 60 miles of a stream course in a year and families range about 3 to 10 miles in a season (Liers 1951). During the spring and summer months, otters spend most of their time within an area of about 4 square miles. There is limited evidence that some otters leave the natal range, but the timing of dispersal is not known (Wilson 1959). Dispersal of family members from the natal range is probably related to the availability of food (Melquist and Hornocker 1983, Chabreck et al. 1985).

Potential Impacts of Dredge Material Disposal:

The river otter is very sensitive to changes in food availability within its range. Any habitat modifications that cause declines in local fish and invertebrate populations may force the otter to abandon the area. Therefore, the greatest potential impacts of construction and operation of dredged material disposal sites on river otters would be habitat alterations or losses that adversely affected the amount and kind of food available.

References:

Baker, O.E., III, and D.B. Carmichael, Jr. 1989. South Carolina's furbearers. Wildlife and Marine Resources Department, Division of Wildlife and Freshwater Fisheries, Columbia.

Chabreck, R.H., J.E. Holcombe, R.G. Linscombe, and N.E. Kinler. 1982. Winter foods of river otters from saline and fresh environments in Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36: 473-483.

Chabreck, R.H., T.L. Edwards, and G. Linscombe. 1985. Factors affecting the distribution and harvest of river otters in Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 39: 520-527.

Lauhachinda, V. and E.P. Hill. 1977. Winter food habits of river otters from Alabama and Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 31: 246-253.

Liers, E.E. 1951. Notes on the river otter (*Lutra canadensis*). Journal of Mammalogy 32(1): 1-9.

Lowery, G.H. 1974. The mammals of Louisiana and its adjacent waters. Louisiana State University Press, Baton Rouge. 565 pp.

McDaniel, J.C. 1963. Otter population study. Proceedings of the Southeastern Association of Game and Fish Commissioners 17: 163-168.

Melquist, W.E. and M.G. Hornocker. 1983. Ecology of river otters in west central Idaho. Wildlife Monographs 83: 1-60.

Wilson, K.A. 1954. The role of mink and otter as muskrat predators in northeastern North Carolina. Journal of Wildlife Management 18(2): 199-207.

Wilson, K.A. 1959. The otter in North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 13: 267-277.

P. Atlantic Bottlenose Dolphin

Atlantic bottlenose dolphin (*Tursiops truncatus*) is a top predator in South Carolina coastal ecosystems, preying on juvenile fish and shrimp. Populations of these large mammals are dependant upon abundant prey, and their presence in high abundance is considered to be an indicator of healthy estuaries. Dolphins are also a charismatic species that have high aesthetic value to the public. Because of their recognized value to the public as well as their importance as top predators, dolphins are an appropriate Representative Important Biota to use for defining and evaluating the impacts of construction and operation of alternative dredged material disposal sites in the Charleston Harbor ecosystem.

Distribution and Ecology:

The Atlantic bottlenose dolphin is a cosmopolitan species, occurring along the coasts of North and South America, Europe, Africa, and Australia (Tomilin 1957, Caldwell and Golley 1965, Sergeant et al. 1970, Ross 1977, Lear and Bryden 1980, Lichter and Hooper 1984). In the Southeast, dolphins mainly reside in the tidewater channels between the sea islands and along the ocean beaches (Golley 1966). Most bottlenose dolphins are year-round residents of a particular area (Caldwell and Golley 1965, Wursig and Wursig 1979). Distributions, however, vary seasonally, probably in response to food availability (Irvine et al. 1981).

Female dolphins reach sexual maturity at 5-12 years and 220-235 cm. Males mature at 10-13 years and 245-260 cm (Odell 1975). Calving occurs in most months with a peak usually occurring in spring (Mead and Potter 1990). Most Atlantic bottlenose dolphins reside within a natal home range. Adults forage around nearshore reefs and sand bottoms, as well as in the deep estuaries. Calves (up to 1 year) primarily feed in shallow waters of the estuaries (Cockcroft and Ross 1990). In South Carolina, major prey species for dolphins are fish and shrimp (Mead and Potter 1990).

Potential Impacts of Dredge Material Disposal:

Because bottlenose dolphins are top predators, the condition of their population reflect the overall condition of the Charleston Harbor ecosystem. Activities associated with construction and operation of dredged material disposal sites in Charleston Harbor that adversely affect spawning and nursery habitats for dolphin prey (fish and shrimp) or that adversely affect migration and movement of fish and shrimp would be expected to adversely affect the bottlenose dolphin abundance. Calves of bottlenose dolphins would be especially vulnerable since they feed primarily in estuaries.

References:

Barros, N.B. and D.K. Odell. 1990. Food habits of bottlenose dolphins in the southeastern United States. Pages 309-328 in S. Leatherwood and R.R. Reeves (eds.). The bottlenose dolphin. Academic Press, Inc., New York.

Caldwell, M.C. and F.B. Golley. 1965. Marine mammals from the coast of Georgia to Cape Hatteras. Journal of Elisha Mitchell Science Society 81: 24-32.

Cockcroft, V.G. and G.J.B. Ross. 1990. Food and feeding of the Indian Ocean bottlenose dolphin off southern Natal, South Africa. Pages 295-308 in S. Leatherwood and R.R. Reeves (eds.). The bottlenose dolphin. Academic Press, Inc., New York.

Golley, F.B. 1966. South Carolina mammals. The Charleston Museum, Charleston, South Carolina.

Irvine, A.B., M.D. Scott, R.S. Wells, and J.H. Kaufmann. 1981. Movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Florida. Fishery Bulletin 79(4): 671-688.

Lear, R.J. and M.M. Bryden. 1980. A study of the bottlenose dolphin, *Tursiops truncatus*, in eastern Australian waters. ANPWS Occasional Papers 4, 25 pp.

Lichter, A. and A. Hooper. 1984. Guia para el Reconocimiento de los Cetaceos del Mar Argentino. Fundacion Vida, Silvestre Argentina, Buenos Aires. 96 pp.

Mead, J.G. and C.W. Potter. 1990. Natural history of bottlenose dolphins along the Central Atlantic Coast of the United States. Pages 165-195 in S. Leatherwood and R.R. Reeves (eds.). The bottlenose dolphin. Academic Press, Inc., New York.

Odell, D.K. 1975. Status and aspects of the life history of the bottlenose dolphin, *Tursiops truncatus*, in Florida. Journal of the Fisheries Research Board of Canada 32: 1005-1058.

Ross, G.J.B. 1977. The taxonomy of bottlenosed dolphins *Tursiops* species in South African waters, with notes on their biology. Ann. Cape Prov. Mus. (Nat. Hist.) 11(9): 135-194.

Scott, G.P. 1990. Management-oriented research on bottlenose dolphins by the Southeast Fisheries Center. Pages 623-639 in S. Leatherwood and R.R. Reeves (eds.). The bottlenose dolphin. Academic Press, Inc., New York.

Sergeant, D.E., A.W. Mansfield, and B. Beck. 1970. Inshore records of Cetacea for eastern Canada. J. Fish. Res. Board Can. 27(11): 1903-1915.

Tomilin, A.G. 1957. Mammals of the U.S.S.R. and adjacent countries. Volume IX, Cetacea. Israel Program for Scientific Translation (No. 1124), Jerusalem. 738 pp.

Wursig, B. 1986. Delphinid foraging strategies. Pages 347-359 in R.J. Schusterman, J.A. Thomas, and F.G. Woods (eds.). Dolphin cognition and behavior: A comparative approach. Lawrence Erlbaum Assoc., Hillsdale, New Jersey. 393 pp.

Wursig, B. and M. Wursig. 1979. Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus*, in the South Atlantic. Fishery Bulletin 77: 399-412.

APPENDIX B

Description of Representative Important Habitats

A. Existing Contained Disposal Areas

Active contained dredged material disposal areas were included in this Representative Important Habitat (RIH) category. These environments have little ecological value as habitat for Representative Important Biota (RIB) and are designed to retain the sediments that are placed in them. Existing contained disposal areas include the Yellow House Creek, Naval Weapons Station, Clouter Creek, Drum Island, and Morris Island sites.

B. Upland Habitat

For the purpose of this study, all non-wetland land cover and uses are included in this RIH category including: residential, industrial, commercial, utility right-of-ways, historical, cleared areas, and natural plant communities (coastal shrub and forested communities). Much of the primary production in wooded coastal habitats falls to the ground where it decomposes. These decompositional processes are important in controlling the flux of materials, especially nutrients, from upland to aquatic habitats. Coastal wooded upland habitats are also important foraging and nesting places for many terrestrial animals including amphibians, reptiles, birds, and mammals. Diverse bird communities nest and forage in the pine forests, including the pine warbler, Bachman's sparrow, bobwhite quail, and screech owl. Terrestrial birds, such as the ground dove, red-winged blackbird, and mockingbird, nest and forage in coastal shrub communities. Bird populations tend to be more diverse and abundant in buffer areas between upland habitat types. Mammals inhabiting coastal upland habitats including rodents, white-tailed deer as well as predators, like the bobcat and fox. Three Representative Important Biota are found in the coastal upland habitats: eastern wild turkey, the great blue heron, and the red-cockaded woodpecker. Wild turkey roosts in pine trees, great blue herons establish nesting colonies in pine forests near water, and the red-cockaded woodpecker is endemic to pine forests.

C. Freshwater Wetlands

The freshwater forested and emergent wetlands that are scattered throughout the candidate upland sites in the low-lying areas (e.g., Parkers Island, Rodent Island, Naval Weapons Station, Point Hope Island) were included in this RIH category. Major freshwater wetland types characterized by the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) that were included are: temporarily-flooded hardwood forests and evergreen forests, seasonally-flooded hardwood forests, semi-permanently flooded emergent wetlands, temporarily-flooded emergent wetlands, and temporarily-flooded shrub/scrub wetlands. The degree and duration of flooding is dependent on the soil type and amount and degree of relief. The temporarily-flooded hardwood wetlands are typically dominated by oaks (i.e., willow, swamp, chestnut, and water oaks), sweetgum, and red maple. The seasonally-flooded evergreen wetlands are dominated by loblolly and slash pine. The seasonally flooded hardwood wetlands are typically dominated by sweetgum, black gum, and red maple. The semi-permanently flooded emergent wetlands are shallow marshes. These marshes are dominated by emergent plants such as pickerel weed, water lilies, and spikerushes. The temporarily-flooded emergent wetlands are predominantly found in cut over forested wetland areas where the hardwoods were salvaged after Hurricane Hugo. These wetlands are in an early successional stage, and will eventually revert to a oak-dominated forested wetland. During site visits, oak seedlings were observed scattered among emergent plants. The emergent wetlands found in cutover forested areas resemble temporarily-flooded emergent wetlands and are dominated by spikerushes, bulrushes, sedges, and blue flag. The temporarily-flooded scrub/shrub wetlands are found along ditches and in open areas within cutover forested wetlands. The dominant species commonly found in this wetland type are: wax myrtle and holly. Freshwater forested and emergent wetlands provide habitat for many rare biota (e.g., Canby's dropwort) and are nursery habitat for amphibians and insects that are an important food source for raptors (e.g., owls), wading birds (e.g., herons), and insectivorous birds. Emergent wetlands are preferred foraging habitat for migratory waterfowl and mammal species, providing a excellent source of grasses and forbs. The hardwood wetlands supply the wild turkey populations with their most important food source - acorns. Forested hardwood and evergreen wetlands provide nesting habitat for herons (i.e., great blue heron) and related species. All types of freshwater wetlands have important roles as sinks for nutrients and sediments protecting the water quality of streams, rivers, and estuaries. These wetlands also have critical roles in controlling hydroperiod and flooding for upland areas.

D. Ponds, Borrow Pits, Impoundments

Borrow pits and impoundments are the two habitat types in this RIH category that occurred at candidate dredged material disposal sites. Borrow pits occur at the Rodent Island and Point Hope Island sites, and impoundments occur at the Lower Thomas Island and Cainhoy Road sites. Borrow pits are excavated areas that function as freshwater ponds. These pits vary in shape from circular pits with steep banks and no rooted vegetation to oblong pits with sloping banks and abundant vegetation cover. Borrow pits frequently provide rookery and foraging habitat for herons and related species. The Point Hope Island borrow pits are documented rookeries for the great blue heron. Borrow pits with steep banks have less productive and diverse aquatic communities and are not optimal foraging habitat for wading birds.

All but one of the impoundments occurring at candidate dredged material disposal sites are diked salt marshes. The remaining impoundment is a diked small creek. All are inundated with saltwater during spring and storm tides. The food webs in impoundments are similar to those of adjacent brackish marshes. Impoundments provide nursery habitat for amphibians and wading birds. Otters, raptors, migratory waterfowl, and other estuarine-dependent mammals also forage in the impoundments. Because they attract dense waterfowl populations, recreational hunters use impoundments as preferred hunting sites.

E. Mixed Estuarine Marshes

Estuarine marshes are a dominant feature of the Charleston Harbor ecosystem. Marsh vegetation characteristic of this habitat, mainly smooth cordgrass and black needlerush, produces an enormous amount of organic material exceeding the productivity of most terrestrial communities of comparable size, even intensively managed cropland. The high productivity of estuarine marshes is mainly due to the diel inundation by water containing relatively high concentrations of nutrients augmented by nutrients in surface runoff from adjacent terrestrial environments. Two salt marsh types (low and high elevation) occur along the Wando River. The low elevation marsh is found primarily in the intertidal zone and is dominated by smooth cordgrass; whereas the high elevation marsh is found above the high tide mark and is dominated by black needlerush. Along the Cooper River, a sharp boundary between the low and high elevation marshes does not exist. In this region, estuarine marshes were classified as mixed elevation salt marsh because plant species characteristic of both high and low elevation zones co-occurred. Only a small amount of the grass which is produced in salt marshes is consumed directly by grazers. Most of it falls to the marsh surface when the plant dies and is decomposed by microbial organisms and small invertebrates. This decaying marsh grass is called detritus and forms the base of a complex salt marsh food web. Low elevation estuarine marshes are important foraging habitat for many wading birds (e.g., great blue heron), waterfowl (e.g., clapper rail), raptors (e.g., osprey), aquatic mammals, and fish (e.g., mummichog, bay anchovy, red drum, summer and southern flounder). This wetland type is also a nursery habitat for many recreationally and commercially important species including red drum, blue crab, and white and brown shrimp. High elevation marshes are important nursery habitat for many birds including the clapper, virginia, king, and sora rails. A few small mammals nest in the high marsh, including the marsh rabbit and rice rat.

F. Tidal Sand and Mud Flats

Tidal sand and mud flats are usually unvegetated although salt tolerant species such as saltwort and salt grass can be found on some high elevation sand flats. Mud flats are generally found lower in the intertidal zone than the elevation at which emergent vegetation flourishes. Occasionally, however, mud flats occur within the smooth cordgrass community. Sand flats are found in the transitional zone between upland areas and high elevation salt marshes or near the mouths of inlets and creeks. Tidal flats were abundant on the Parkers Island, Point Hope Island, and Rodent Island sites, as well as at the Fort Johnson site. The major primary producers of tidal flats are benthic microalgae, such as diatoms and blue-green algae. The production of these bottom-occurring algae frequently exceed phytoplankton production in shallow and turbid, coastal waters and may contribute up to one third of overall ecosystem primary production. The permanent residents on sand and mud flats are mainly bottom dwelling invertebrates which live in and on the sediments including oysters, clams, and crabs as well as segmented worms and small crustaceans. These biota have important roles in the breakdown of detritus, and many species of fish, birds, and small mammals come to tidal flats to feed upon them. Several Representative Important Biota feed extensively on mud flats (i.e., red drum, blue crab, great blue heron). Tidal flats also have important roles in estuarine material cycles.

G. Small Tidal Creeks

This RIH habitat category encompasses tidal creeks and their tributaries with an average depth of ≤2 meters (6.6 feet) at mean high water. Because the tidal amplitude in the Charleston Harbor ranges from 1.8 to 2.0 m, small tidal creeks and their tributaries are exposed during low tide. The bottom dwelling organisms that permanently reside in this habitat, including the oysters and clams, are physiologically adapted to the extreme changes in environmental conditions that are associated with the rising and falling of tides. These shallow tidal creeks are particularly important nursery grounds for many commercially and recreationally important marine species (e.g., red drum, spotted seatrout, summer and southern flounder, blue crabs, and penaeid shrimp). Shallow tidal creeks are also important foraging habitat for wading birds and many mammals. Recreational fishermen frequently fish in small tidal creeks on rising tides to catch larger predatory fish that are entering the small tidal creeks to forage on the abundant populations of smaller organisms.

H. Large Tidal Creeks and Rivers

This RIH habitat category encompasses all creeks with an average depth ≥2 meters (6.6 feet) at mean high tide. It mainly includes the Wando and Cooper rivers. Deep tidal creeks are permanently flooded and provide migrational routes for movement of seasonal migrants like white shrimp, blue crab, and red drum to their nursery habitat. Migratory fish (e.g., herrings, striped bass, eels) also use large tidal creeks as conduits to and from their spawning grounds. During winter, the deeper portions of large tidal creeks provide a refuge for overwintering fish (e.g., red drum, spotted seatrout), white shrimp, and blue crab from extreme winter temperatures. Selected deeper portions of large tidal creeks, such as the portion of the Wando River in the vicinity of the Cooper River Bridge, are known to be spawning sites for spotted seatrout. Many species of diving birds (e.g., gulls, terms, skimmers, pelicans) prey upon the abundant populations of juvenile fish that accumulate in large tidal rivers. Large tidal creeks and rivers are also preferred fishing sites for humans, particularly the portion of the Cooper River in the vicinity of the north end of Drum Island. The port and Naval facilities in Charleston Harbor are located in large tidal rivers.

I. Shallow Estuary

Subtidal estuarine areas ≤ 2 meters (6.6 feet) deep with a salinity greater than 20 ppt were included in this RIH category. These areas are found between the Fort Johnson site and the existing Morris Island dredged material disposal site in Clark Sound. Because the tidal amplitude in Charleston Harbor ranges from 1.8 to 2.0 m, shallow estuarine habitats are usually flooded during high tide and exposed at low tide. Shallow estuarine habitats serve all the ecological functions previously discussed for small tidal creeks. Because they are characterized by particularly abundant populations of oysters, clams, and shrimp, these habitats are extensively used by humans for shellfishing. Shallow estuarine habitat is also preferred foraging habitat for wading birds.

J. Deep Estuary

Subtidal estuarine areas ≥ 2 meters (6.6 feet) deep with a salinity ≥ 20 ppt were included in this RIH category. These areas were predominantly found from the confluence of the Wando and Cooper rivers to the mouth of the Charleston Harbor proper. Deep estuarine habitat serves all the ecological and human use functions previously discussed for large tidal creeks and rivers. In addition, this RIH is extensively used by humans for boating. It also provides transportation routes for shipping traffic to port facilities.

K. Coastal Dunes and Beaches

Intertidal beaches as well as coastal dunes were included in this RIH category. In the study area, beaches were found in the vicinity of the Middle Shoal site and at the Fort Johnson and Morris Island sites. Coastal dunes were found only at the Morris Island site. Coastal beaches and dunes represent physically extreme environments, and relatively few biota have the adaptations to occur here. As a result, the biodiversity of the coastal dune and beach habitat is low. The bottom dwelling biota that can tolerate the extreme conditions of coastal beaches are, however, frequently abundant and provide forage for the many species of shorebirds (e.g., sandpipers, plovers) and nearshore fishes (e.g., whiting, spot). Coastal dunes are important nesting habitat for sea turtles, and the endangered loggerhead turtle has been reported to nest on coastal beaches near the Morris Island site. Coastal dune habitats are a seed- and grass-rich environment, providing food for many birds such as doves, sparrow, and blackbirds. Raptors and insectivorous birds also frequent the dunes, preying on the insects, birds and small mammals that forage and nest in the area. Dunes are an important nesting and resting habitat for the American oyster catcher, black skimmer, various gulls and terns. Perhaps the most important function of coastal dunes is the protection it provides adjacent upland habitats from erosion during storms. Humans use coastal beaches for fishing, swimming, and other recreational activities.

L. Shallow Coastal Water

Coastal ocean habitats between beachfront and 10 m (<33 ft) were included in this RIH category. These areas provide important nursery habitat for many species of commercially and recreationally important fish including Atlantic croaker, spot, spotted seatrout, weakfish, and whiting. Shrimp are particularly abundant in this habitat in summer and fall as they migrate from their estuarine nursery habitats into coastal waters, and most of the commercial shrimp catch is taken from shallow coastal waters. Shallow coastal waters are accessible to small boats and are used by a range of recreational fishermen seeking to catch Spanish mackerel, king mackerel, red drum, and other large predator fish that prey upon the small fish that use this habitat as a nursery.

M. Deep Coastal Water

Coastal ocean habitats ≥10 m (~33 ft) in depth were included in this RIH category. These oceanic environments generally have high water quality and provide habitat for many pelagic game fish which are highly sought by recreational fishermen including dolphin, Spanish and king mackerel, wahoo, tuna, white and blue marlin, and sailfish. These predatory fish feed on the abundant supply of pelagic forage fish that occur in this habitat (e.g., menhaden, mullet, herrings, flying fish). The sand bottom habitat that is characteristic of this environment is dominated by bottom dwelling organisms that burrow below the sediment surface. It is generally not as productive as comparable estuarine bottom habitats.

N. Live Bottom Habitat

Live bottom habitats are best developed in coastal waters ≥18 m (~60 ft) where exposed rocky outcrops and a high degree of bottom relief occurs. They, however, do occur in shallow coastal waters. These habitats contain diverse assemblages of large sessile invertebrates (e.g., sponges, soft and hard corals, tunicates and sea fans). Abundant and diverse populations of small invertebrates that are prey for larger fish are associated with the sponges and corals. Many recreationally and commercially important fish (e.g., snapper, grouper, mackerel) aggregate in the vicinity of live bottom habitats. In a sense, live bottom habitats resemble an oasis in a desert. Compared to adjacent sand bottom habitat, the amount of live bottom habitat in coastal waters is limited (5-30% in the mid-Atlantic). Because of the abundant populations of fish, live bottom habitats are also locations where offshore fishermen aggregate.